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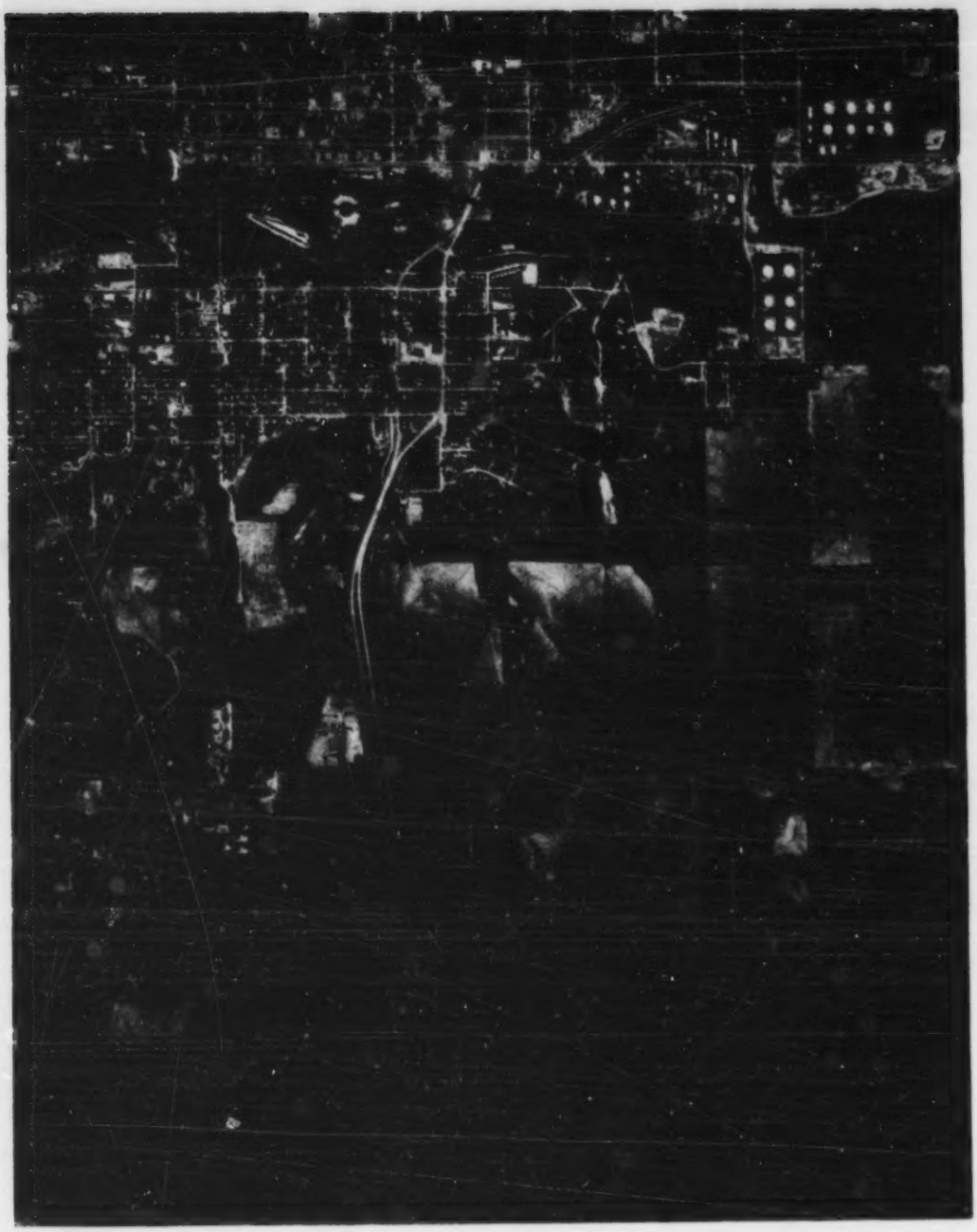

Canada Department of Energy, Mines and Resources Photo - Aerial View of the Moose Jaw River through the City of Moose Jaw

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COVER PHOTO: *Saskatchewan Government Photo* - Downtown Moose Jaw from the South Shore of the C.P.R. Reservoir

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MOOSE JAW RIVER STUDY

REPORT OF
THE QU'APPELLE BASIN STUDY BOARD
CANADA - SASKATCHEWAN - MANITOBA

FEBRUARY, 1974

LETTER OF TRANSMITTAL

Regina, Saskatchewan
February, 1974

Honourable Jack Davis
Minister, Environment Canada

Honourable Neil E. Byers
Minister, Saskatchewan Department
of the Environment

Honourable Sidney Green
Minister, Manitoba Department of Mines,
Resources and Environmental Management

Gentlemen:

A study of the Moose Jaw River through the city of Moose Jaw has been undertaken in accordance with the Supplementary Qu'Appelle Basin Agreement between the Governments of Canada, Saskatchewan and Manitoba dated July 24, 1972.

The purpose of the study was to develop a plan to reduce water pollution, maintain stable water levels and provide flood control and flood plain management for the city of Moose Jaw. Detailed studies were undertaken to define the problems and a range of management alternatives were considered. The results are summarized in this report and documented in greater detail in the supporting appendices. On the basis of the findings and conclusions of these studies the Board has recommended a number of courses of action for alleviating water management problems in Moose Jaw.

Respectfully submitted,

G. C. Mitchell, Chairman
Saskatchewan Department
of the Environment

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SYNOPSIS

In 1972 Canada, Saskatchewan and Manitoba agreed to undertake a study, supplemental to the Qu'Appelle Basin Study Agreement, to examine water management problems on the Moose Jaw River in the city of Moose Jaw. The study was conducted by the Inland Waters Directorate, Western Region, Environment Canada under the direction of the Qu'Appelle Basin Study Board.

The main problems considered in the study were urban damages resulting from spring floods, the inadequate water supply in the river during the summer months and the poor quality of water in the reservoirs created by four impoundments within the city.

The flood plain within the city is predominantly in open space or recreational uses, however, a number of areas have been developed for commercial, industrial and residential use. Floods with a probable frequency of occurrence of less than 10% cause damage in the developed area of the flood plain. There are 140 residential buildings and an estimated residential population of 475 persons located on the flood plain. The most significant damage occurs in the residential areas, particularly in the subdivision of Churchill Park where 70% of the residences and 70% of the residential population are located. The average annual damage from floods of all frequencies of occurrence was estimated at $6,425; the present value of this annual damage is $88,670.

Four impoundments - the Kingsway, C.P.R., High Pressure, and Gulf Dams - create a fairly extensive water surface throughout the length of the river within the city limits. The water supply

problems relate to the aesthetic and recreational value of the reservoirs created by these impoundments. Since there is normally little or no flow in the river after the spring run-off the surface levels in the impoundments recede and the water stagnates throughout the summer. Over the years sediments have accumulated along the river banks creating shallow water conditions near the shore that promote the growth of bull rushes.

The most obvious water quality problem within the city is the growth of algae and aquatic weeds, supported by an overabundance of nutrients: phosphorus, nitrogen and carbon.

The water supply and water quality characteristics combine to detract from the aesthetic appeal and restrict the recreational use of the river.

A number of alternative courses of action were examined as possible solutions to one or more of the water management problems in Moose Jaw. These included upstream storage, dredging, modification of water control structures, dykes, land use controls, flood proofing, flood forecasting, flood warning and emergency action programs, control of nutrient sources, and control of algae and aquatic weeds.

It was determined that structural measures for flood control are not feasible from an economic point of view. The most effective means of limiting flood damage in the immediate future are through improving flood forecasts together with more effective flood warning and emergency action programs. A number of land use controls could be initiated that would reduce the potential for flood damage over the long term.

Upstream storage would be an effective means of augmenting stream flow through the city. Reservoirs of sufficient capacity to provide a significant year round flow would be costly. It was determined, however, that a reservoir with as little as 200 acre

feet of storage, if located within five miles upstream of the city limits, could provide enough water to maintain the Kingsway and C.P.R. Reservoirs at the full supply level during the months of July and August. A larger reservoir, depending upon its capacity, could supply enough water to maintain all four impoundments in the city at their full supply level throughout the summer months, and provide a substantial, visible flow in the river.

The nutrient concentrations in the Moose Jaw River are more than adequate to support growths of algae and aquatic weeds in the reservoirs within the city. To limit the potential for algal and aquatic weed growth the nutrient concentrations must be reduced both within, and upstream of, the city. It is unlikely that augmentation of stream flow would achieve the desired concentrations unless a nutrient-free source of water was available. A number of chemical and mechanical methods for controlling algae and aquatic weeds during the summer months were investigated.

On the basis of the findings and conclusions of this study the Qu'Appelle Basin Study Board recommended a number of programs for implementation in the Moose Jaw River Basin.

RECOMMENDATIONS

The Qu'Appelle Basin Study Board, in framing recommendations for flood plain management in the Qu'Appelle Basin, adhered to the philosophy of protecting existing developments on the flood plain where it is economically feasible to do so and leaving the remainder of the flood plain to the river. This philosophy is particularly applicable to the Moose Jaw River flood plain in the city of Moose Jaw where there is at present very limited development, where there are no constraints on growth in other areas that require further development of the flood plain, and where the river valley in which the flood plain is located has a high amenity value as recreation land or park land. Since the potential for damage from floods in Moose Jaw is not great and the cost of structural protective measures is high, it is not economically feasible to recommend the implementation of any of the flood control measures that were investigated. Other factors such as social disruption or the threat of loss of life are not such as to justify the expenditures involved in flood control.

The Board thus recommends a flood plain management plan which is principally directed at achieving the long range planning objective of minimizing the potential for property damage, economic and social disruption, and loss of life from floods. The key elements in the plan are the enactment of a zoning by-law to control development in flood hazard areas, the preparation and dissemination of flood hazard maps, and a limited long-term program of land use change. A program for flood forecasting, warning and emergency action provides a greater opportunity to reduce damage to existing development.

The key element in a water quality management plan for the Moose Jaw River is the control of algal and weed growth. An experimental program for chemical control of algal and weed growth in the impoundments within the city is recommended. A number of programs are also recommended which relate to nutrient removal and to other pollutants in the system.

It is not possible to recommend year round augmentation of the flow of the Moose Jaw River due to the high costs involved in providing upstream storage and the limited benefits which would accrue to flood control and water quality. There are, however, grounds for recommending the construction of a small upstream storage reservoir for some degree of flow augmentation during the summer months. Maintaining the Gulf, C.P.R., and Kingsway Dams and effecting some minor repairs where necessary could enable these impoundments to be maintained near the full supply level if water is available. Some dredging operations in the C.P.R. Reservoir are recommended to improve the aesthetic and recreational value of this body of water and to remove contaminated sediments.

Accordingly, the Qu'Appelle Basin Study Board makes the following recommendations for flood plain, water quality, and water quantity management in the Moose Jaw River.

1. It is recommended that the flood plain of the Moose Jaw River within the city of Moose Jaw, defined as the area inundated by the Probable Maximum Flood, be zoned to restrict development that would significantly increase the potential for flood damage, and that the city of Moose Jaw prohibit construction on the flood plain until appropriate zoning regulations have been implemented.

No further residential, commercial or industrial development on the flood plain should be allowed. Certain types of development, such as recreation, are consistent with proper use of the flood plain, and may be specified as permitted uses. However, any development that is permitted should be regulated to minimize the potential for damage from floods.

2. It is recommended that flood hazard maps of the flood plain through the city be prepared and made available to interested government and private agencies and individuals.

As a result of the Moose Jaw River Study the information required to produce flood hazard maps is available. This information should be accessible to any interested party in an easily reproducible and understood form.

3. It is recommended that a long term program for the acquisition of land on the flood plain be adopted.

The purpose of this program would be to change the present use of land in flood risk areas to uses with less potential for loss. For example, the present policy of the city of Moose Jaw of acquiring land in Kingsway Park should be continued with a view to phasing this area out as a residential area. The residential land in Wellesley Park should be purchased as it becomes available with a view to converting this area entirely to park or urban open space.

4. It is recommended that the Saskatchewan Department of the Environment's flood forecasting program for the Moose Jaw River be improved and expanded to include a detailed flood warning and emergency action program for the city of Moose Jaw, and that the Department be responsible for the implementation of this program in cooperation with the appropriate government agencies and private organizations.

Flood forecasts for the Moose Jaw River are at present provided through the Saskatchewan Department of the Environment's monitoring program for operation of the Qu'Appelle River System. The Department is developing an improved flood forecasting system for the Moose Jaw River Basin, and this should be adopted as soon as possible. Detailed flood warning and emergency action procedures should be designed, and the responsibility for implementing these procedures should be clearly established.

5. It is recommended that a program be developed to encourage flood proofing of existing structures on the flood plain that are susceptible to flood damage.

The province of Saskatchewan should develop the details of a flood proofing program for administration at the local government level. Technical advice should be provided to all flood plain occupants.

6. It is recommended that future construction activity in the city adjacent to the river, particularly bridge construction, be sub-

ject to the approval of the Saskatchewan Department of the Environment to ensure the avoidance of unnecessary constriction of the channel.

There are several areas through the city where construction activity has reduced the river channel capacity. There are also several older bridges that act as constrictions during floods and others that have the potential to trap debris during floods, with a consequent loss of channel capacity. Future construction activity along the river, including replacement of existing works, should be controlled to minimize reductions in channel capacity.

7. It is recommended that sewage effluent from the Canadian Forces Base be transported to the Moose Jaw City sewage treatment plant for treatment.

Effluent from the Canadian Forces Base is discharged into the Moose Jaw River upstream from the city of Moose Jaw. Since the flow in the river is negligible after the spring run-off, most of the effluent is impounded by the small dams within the city. The nutrients present in the effluent are sufficient to support substantial algal blooms in these impoundments during the summer months. The continued contribution of nutrients from this source would nullify the effect of any reduction in nutrient loading upstream.

8. It is recommended that a program to control practices that contribute nutrients to surface waters be developed and implemented in the basins above Moose Jaw.

Nutrient levels in the Moose Jaw River near the city above the Canadian Forces Base outfall are sufficiently high to support substantial algal blooms in impoundments during the summer months. Practices that contribute nutrients to the river must be controlled if nutrient levels are to be reduced.

9. It is recommended that immediate steps be taken to identify and to control unknown point sources of river pollutants.

Although several sources of pollution discharging into the Moose Jaw River above and within the city have been identified, a more complete inventory and control program is required.

10. It is recommended that further study be undertaken to identify the source of fecal coliform bacteria in the Moose Jaw River.

Highly variable levels of fecal coliform bacteria have been noted in the river waters at various times although there is no known source of untreated sewage discharge to the river.

11. It is recommended that an experimental program for control of algae and weeds in impoundments on the Moose Jaw River within the city be implemented immediately.

A number of methods are known to be effective in controlling the growth of algae and aquatic weeds, however, details of control programs, and thus the costs, can only be determined through practice. A program should be developed to meet requirements for algal and weed control in the city of Moose Jaw.

12. It is recommended that an intensive program to clean up the shoreline of the Moose Jaw River through the city of Moose Jaw be implemented.

Extensive areas of both publicly and privately owned shoreline are littered with trash and debris. A coordinated effort to remove this material would improve the visual aesthetics of the river. For example, if the Saskatchewan Power Corporation land adjacent to the river near the C.P.R. Dam was cleaned up and properly managed it would enhance the aesthetic value of this potentially attractive area of the river. Similar benefit would result from a clean-up of Gulf Oil land adjacent to the Gulf Reservoir and city land downstream from the Gulf Dam.

13. It is recommended that portions of the Moose Jaw River and Thunder Creek within the city limits be dredged to enhance the water quality and the aesthetic and recreational potential of the C.P.R. Reservoir.

Dredging portions of the shoreline of the C.P.R. Reservoir from the C.P.R. Dam to a point immediately downstream from the swimming area in City Park, to provide a minimum depth of water of about five feet, would enhance the aesthetic and recreational potential of the reservoir. The areas to be dredged are identified in Figure 13 of this report.

There are a number of additional areas where dredging of the bottom sediments may improve water quality in the river. The principal areas identified were above Kingsway Dam, the C.P.R. Reservoir at the mouth of Thunder Creek, and above the High Pressure Dam. The depth and extent of dredging necessary in these areas to improve

water quality are unknown, and would have to be delineated to estimate costs.

14. It is recommended that the C.P.R. Dam be thoroughly inspected, and any repairs necessary to achieve reliable operation and maximum control of leakage be carried out. It is further recommended that the High Pressure Dam be repaired or replaced to allow it to continue to serve its present function as a bridge and sewer crossing.

The C.P.R. Dam is the major control structure for static levels within the city. Maintenance of these levels at a maximum, given the existing low summer flows in the river, is highly dependent on the water-tightness of this structure. The structure must also be capable of being easily opened to allow passage of a spring flood crest and then rapidly restored to its water-tight condition.

15. It is recommended that a storage reservoir be constructed on the Moose Jaw River upstream from the city of Moose Jaw to provide increased flows through the city during the summer months.

A controlled reservoir immediately upstream from the city, with as little as 200 acre feet of usable storage, if used only to augment flows through the city during July and August, could provide enough water to replace the flow lost due to diversion of Canadian Forces Base effluent to the Moose Jaw Treatment Plant, and to make up for evaporation losses on the Kingsway and C.P.R. Reservoirs.

A larger reservoir, depending upon its capacity, could supply enough water to maintain all the impoundments in the city at their full supply level throughout the summer months, and provide a substantial visible flow in the river.

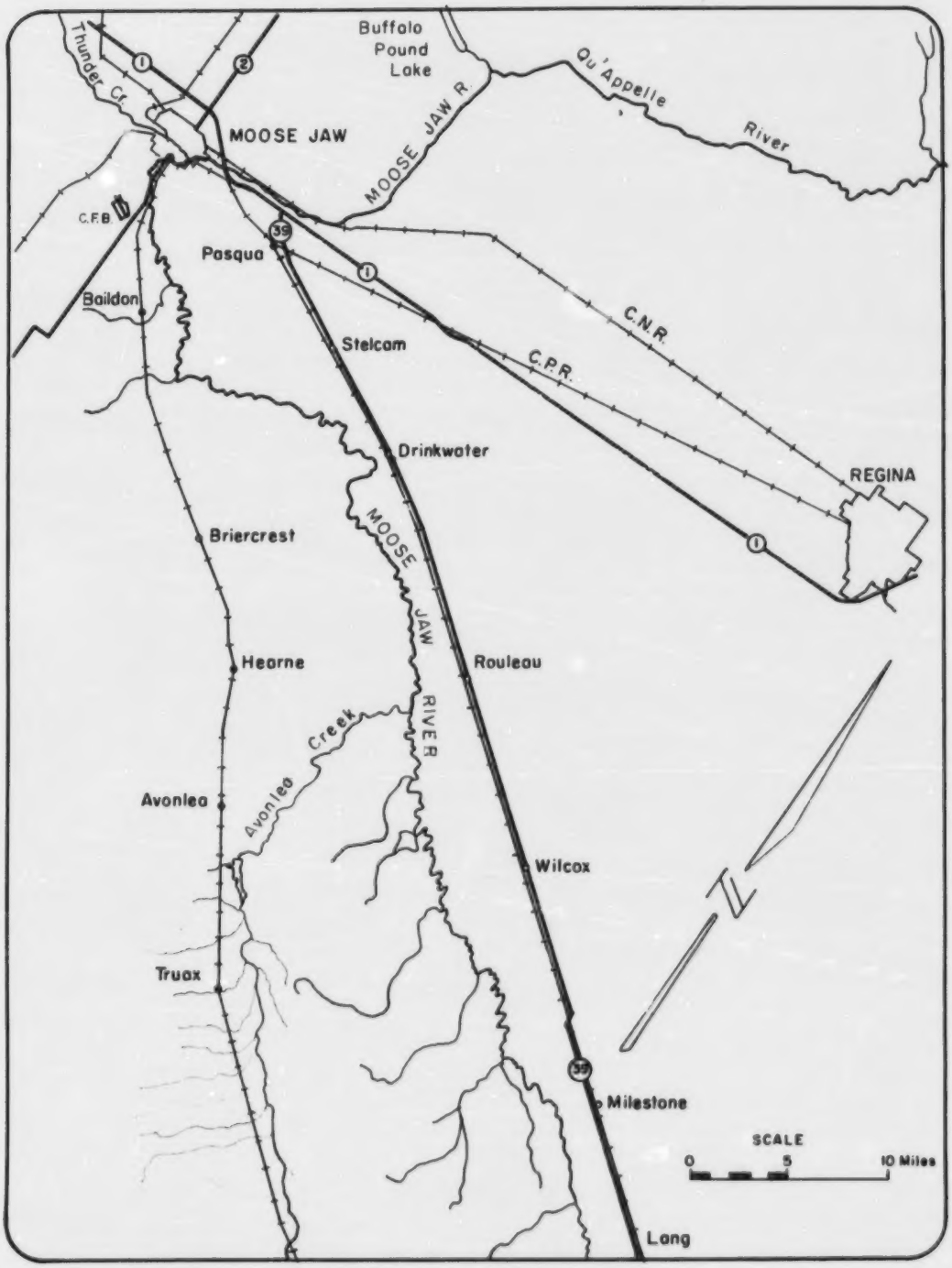


FIGURE I - LOCATION MAP

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

The Moose Jaw River, which flows through the city of Moose Jaw, is a major tributary of the Qu'Appelle River. From its headwaters near Weyburn, the river flows 95 miles to the north-west along the foot of the Missouri Coteau to the city of Moose Jaw, from where it flows a further 25 miles north to its confluence with the Qu'Appelle River below Buffalo Pound Lake. The location of the Moose Jaw River and the city of Moose Jaw are shown in Figure 1.

The Moose Jaw River is a narrow, shallow stream seldom exceeding seven feet in depth. It has an effective drainage area of approximately 550 square miles above the city of Moose Jaw. The flow of the river is almost entirely dependent upon surface run-off. As a result, it generally carries high flows, occasionally reaching flood proportions, during the period from March to June, with little or no flow throughout the remainder of the year.

Within the city of Moose Jaw, the river meanders along the floor of a valley approximately 250 feet in depth and varying from one-half to one mile in width. Near the centre of the city the river is joined by its major tributary, Thunder Creek, which flows from the west. Although most of the river valley land within the city is used for agriculture or recreation, or is undeveloped open space, there is residential and industrial development in some areas. Figure 5 shows the use of river valley land within the city limits.

There are four impoundments on the river within the city limits. These are the Kingsway Dam and the C.P.R. Dam, originally built by the Canadian Pacific Railway as part of a series of dams

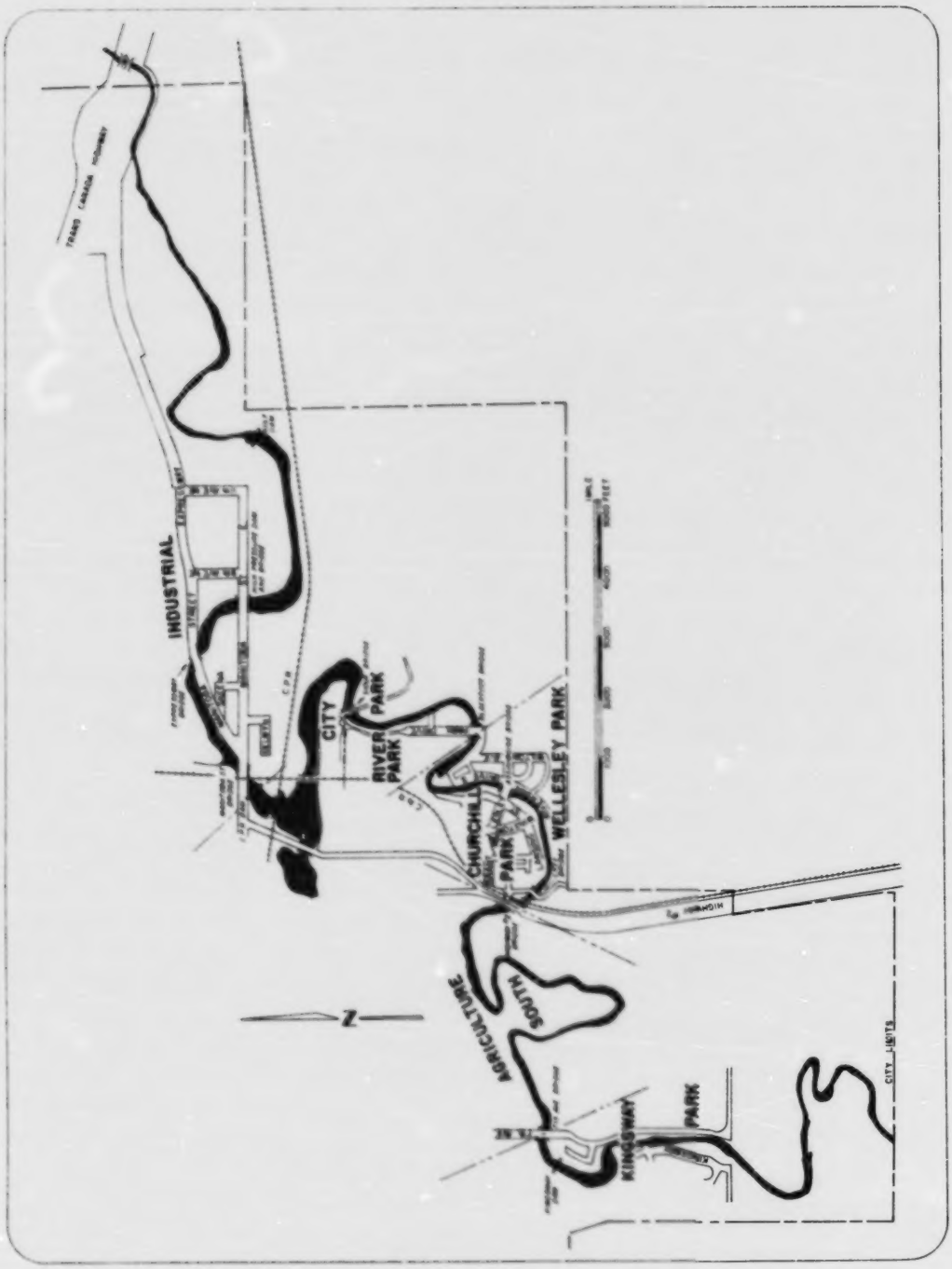


FIGURE 2 : DESIGNATED REACHES - CITY OF MOOSE JAW

built on the river to ensure a supply of water for steam locomotives; the High Pressure Dam, built by the city to provide a supply of water for fire fighting in the central business district; and the Gulf Dam, built to supply water for a petroleum refinery located in the city. The locations of these impoundments are indicated in Figure 2 and some of their characteristics are detailed in Table 1.

The city of Moose Jaw owed its early development to its choice as a major terminal on the C.P.R. Main Line and as the northern terminus of the C.P.R. Soo Line to Minneapolis-St. Paul. It grew as an

City of Moose Jaw Photo - Canoeing on the C.P.R. Reservoir in Moose Jaw

TABLE I : DAMS IN CITY

NAME OF DAM	APPROX. CONSTR. DATE	FULL SUPPLY LEVEL (elev.)	CURRENT RESERVOIR CAPACITY (acre-ft.)	STRUCTURE LENGTH (ft.)	OVERALL HEIGHT OF STRUCTURE (ft.)	SPILLWAY TYPE	NO. OF BAYS	CREST LENGTH	SPILLWAY SILL ELEVATION	CONSTRUCTION MATERIAL(S)	CURRENT CONDITION	REMARKS
Kingsway	1912	1776.7	n/a	130 (approx)	13	Uncontrolled Rock Weir	1	130 (approx)	1776.7	Timber Weir Covered By Rock Fill	Good	Reservoir largely silted. Original timber structure covered by rock weir (1971).
C.P.R.	1912	1765.0	350	452	24	Gated Breast Wall Stop Logs	8	148	1759 to 1759.5	Concrete on timber piles. Timber stop logs.	Good	Structure repaired in 1971.
High Pressure	1912	1760.4	66	138	25	Gated Weir	11	122	1757	Concrete Timber Gates	Poor	Gates not operational. FSL shown is Gulf Dam FSL. Original FSL 1760.
Gulf	1952	1760.4	185	102	28	Gated Weir 1 Bay Gated, 4 Bays Stop Logged	5	90	1752.4	Concrete Steel Gate Timber Stop Logs	Very Good	

agricultural service center and as a processing center with a flour mill and two oil refineries. In the early 1950's, the Canadian Forces Base (CFB) south of the city was re-opened as an air training center and the Saskatchewan Training School was established. The city's population peaked at slightly over 33,000 in 1961. Changes in the transportation industry and economic inefficiencies in processing industries in the past decade have had a dampening effect on economic and population growth in Moose Jaw. The flour mill and one of the petroleum refineries ceased operation during this period, and the second petroleum refinery was converted to an asphalt plant. The C.P.R. which employed 2,400 workers in Moose Jaw in 1950 now employs only about 800. The population of Moose Jaw was recorded at 31,284 in the 1971 census. Some small industries have been attracted to the city in recent years, so that population and economic growth are somewhat static at present. No startling changes in this pattern are anticipated in the immediate future.

The city of Moose Jaw has experienced five significant floods on the Moose Jaw River in the past twenty-five years. The capacity of the channel of the Moose Jaw River within the city is adequate to pass flows of up to 3,000 cfs without overbank flooding. The greatest flood potential exists when peak flows on the Moose Jaw River and its tributary Thunder Creek reach the city simultaneously. The flood of record occurred in 1969 when the peak flow of the Moose Jaw River at Burdick, just downstream from the city, was recorded at 7550 cubic feet per second. The maximum recorded daily discharge of the Moose Jaw River at stations immediately above and below the city of Moose Jaw for the five most recent flood years are indicated in Table 2.

Total costs resulting from the 1969 flood in Moose Jaw have been estimated in previous studies at $70,000. Direct costs, mainly property damage, were estimated at $57,000 of which residential property damage accounted for about $38,000. Costs of the 1948 flood,

TABLE 2: MAXIMUM DAILY DISCHARGE FOR SELECTED FLOOD YEARS MOOSE JAW RIVER

Year	Above Thunder Creek[1]	Near Burdick[2]
1948	not available	7100
1953	not available	3430
1955	3730	3810
1969	5790	7550
1971	3470	4170

[1]This station is located at McCarthy's farm in N.W. 1/4 Sec. 16, Twp. 16, Rge. 26, W2.

[2]This station is located in S.E. 1/4 Sec. 5, Twp. 17, Rge. 25, W2.

which was of similar magnitude to the 1969 flood, have been estimated at $50,000.

In the past the Canadian Pacific Railway and one of the petroleum refineries were dependent for their operation on water withdrawn from the Moose Jaw River, and the city relied on the river as an auxiliary source of water for fire fighting in the central business district. The impoundments on the river were constructed to ensure a firm supply of water for these uses. However, the railway has converted from steam to diesel locomotion and the municipal water supply, which is withdrawn from Buffalo Pound Lake on the Qu'Appelle River, is adequate to provide for the city's needs and those of the

petroleum refinery, which has been converted to an asphalt plant with a much smaller water demand. Thus, there are no significant water withdrawals from the river within the city of Moose Jaw. The main reason for maintaining a water supply in the river is to provide for recreation and to enhance the aesthetic value of the river. As has been noted, there is virtually no flow in the Moose Jaw River in most years after the month of June. However, the cumulative effect of the four impoundments is to create a fairly extensive water surface throughout the length of the river within the city. About two feet of water is lost from these water surfaces annually through evaporation.

There are a number of sources of pollution on the Moose Jaw River and on Thunder Creek within the city. The city of Moose Jaw

Saskatchewan Government Photo - Sandbagging in Moose Jaw during the 1969 Spring Flood

discharges effluent from its sewage lagoons into the river immediately below the Gulf Dam, and the CFB discharges effluent from its treatment plant into the river at a point about two miles above the city limits. The Gulf Oil refinery was a significant source of pollution during the period that it was in operation, degrading the water in the reservoir and downstream from the Gulf Dam. At the time the refinery ceased operation in October, 1971, the reservoir was badly contaminated with coke fines and oily deposits in the bottom sediments. On Thunder Creek there are a number of cattle feedlots within the western extremity of the city limits, a tank car cleaning facility operated by CGTX and the C.P.R. railway yards.

Since 1970 significant steps have been taken to reduce the pollution load from most of these sources, and steps to provide for a higher level of sewage treatment by the Canadian Forces Base and the city of Moose Jaw are anticipated upon implementation of the January, 1973 recommendations of the Qu'Appelle Basin Study Board. Residents and elected officials of the city of Moose Jaw are, however, still not satisfied with the quality of water in the Moose Jaw River. The river is silty and during the summer months is laden with algae and weed growth. City officials are reluctant to re-open the bathing beach located near the Sioux Bridge which was closed in 1969 due to high bacterial counts. During the summer months when there is no flow in the river the water stagnates and is aesthetically unattractive.

Siltation in certain reaches of the river has led to dense growths of bull rushes and other vegetation, which are regarded as unsightly by city officials and detract somewhat from the use of the river and the river banks.

The problems of water quantity, water quality, and sedimentation all relate primarily to the aesthetic appeal of the river and adjacent bank areas. These problems are compounded by the unsightly condition of the river and its environs in certain reaches due to

City of Moose Jaw Photo - Feedlots Along Thunder Creek on the Western Outskirts of Moose Jaw

accumulations of debris in the river and on the river banks, and by careless use and poor maintenance of areas adjacent to the river.

1.2 THE PRESENT STUDY

The Moose Jaw River has been the subject of previous studies, the most comprehensive of which were the Moose Jaw River Phase I and Phase II Studies coordinated by the Saskatchewan Water Resources Commission in the late 1960's. The final phase of that three-phase study had not been undertaken at the time the Qu'Appelle Basin Study was

Photo by J. E. Glenn - River Bank Below C.P.R. Dam in Moose Jaw

initiated in 1970. Some steps were taken as a result of the Phase I and Phase II Studies however, particularly with respect to water quality.

The Qu'Appelle Basin Study examined certain problems on the Moose Jaw River, including water quality and flooding in the city of Moose Jaw. It was apparent, however, that since this study was concentrated on the main stem of the Qu'Appelle, enough attention could not be given to all the problems in Moose Jaw to provide solutions.

In the summer of 1972, Canada, Saskatchewan, and Manitoba - the parties to the Qu'Appelle Study Agreement - agreed to undertake supplementary studies concerning pollution, the maintenance of stable water levels and flood plain management on the Moose Jaw River in the city

of Moose Jaw. The objectives of the Supplementary Agreement as they relate to the Moose Jaw River are to develop a plan to reduce water pollution, maintain stable water levels, and provide flood control and flood plain management for the city of Moose Jaw. These objectives were further refined on the basis of discussions at meetings with elected and appointed officials of the city of Moose Jaw.

The task of conducting studies and preparing a report on the Moose Jaw River was assigned to the Western Region, Inland Waters Directorate, Environment Canada. A number of studies were conducted to provide the information necessary to develop and evaluate alternative courses of action related to the study objectives. A map with a 2-foot contour interval was prepared for the area adjacent to the river; cross sections were surveyed at 57 stations along the course of the river within, and immediately adjacent to, the city to provide information for hydrology and sedimentation studies; hydrographs were prepared for natural flow conditions and for a range of probable flood events on the Moose Jaw River; water surface profiles were determined using a computer program, and land areas which would be inundated when peak flow conditions occurred were mapped for the various flood events; the area within the flood plain was inventoried to determine the number and type of buildings and other property on the flood plain; and stage damage and frequency damage relationships were determined. Various structural alternatives, such as dams, dykes, and channel modification for flood control and for water supply were identified. Where previously available information concerning the design and costs of structural alternatives was available, it was reviewed and updated. Where such information was not available, preliminary designs and cost estimates were prepared. The effectiveness of the structural alternatives was tested with the hydrology model and, in the case of flood control alternatives, evaluated using the frequency damage relationships. Land use and land ownership on the flood plain were determined and mapped,

and a questionnaire survey of residents on the flood plain was undertaken to provide additional information, particularly concerning circumstances related to the 1969 flood. Information was compiled concerning other alternatives such as land use and zoning, and flood forecasting, warning and emergency action.

A water quality sampling and analysis program was conducted to expand the basic inventory of water quality obtained during the Qu'Appelle Basin Study, and information concerning point sources of pollution was evaluated. Sedimentation studies estimated sediment yields for various flood frequencies and the amount of sediment trapped in selected reservoirs.

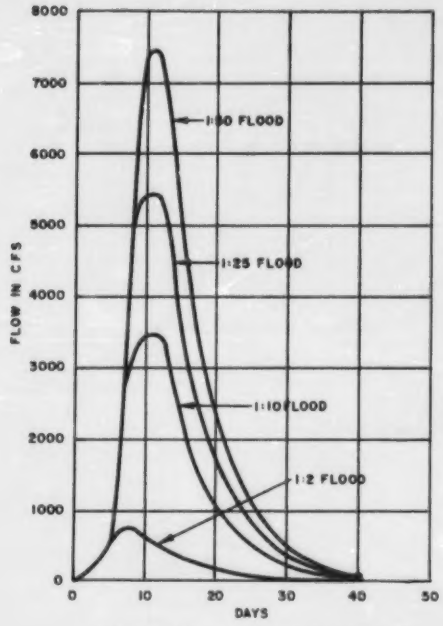
More detailed information concerning the scope, the methodologies and the results of the various studies undertaken is found in the appendices to this report. The remainder of this report is directed primarily at examining management alternatives identified in these studies. Chapters 2, 3, and 4 include discussions of specific problems and planning objectives, and the presentation and evaluation of various management alternatives for flood plain management, water quantity, and water quality respectively. Chapter 5 is a discussion and assessment of planning alternatives and Chapter 6 reviews the findings and conclusions of the study.

CHAPTER 2
FLOOD PLAIN MANAGEMENT

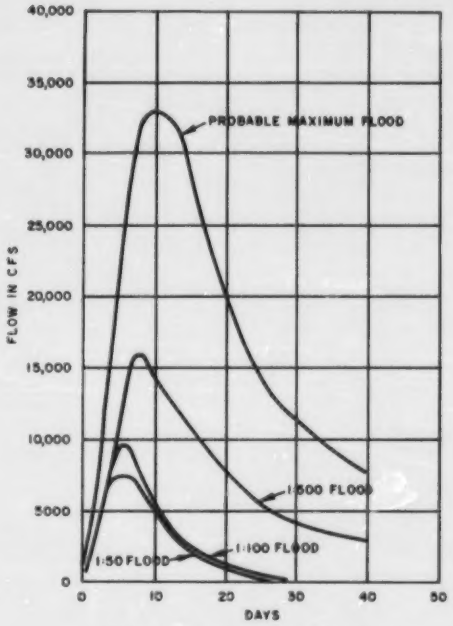
2.1 THE FLOOD HAZARD

Floods are "chance" occurrences. It is not possible to predict in advance what the flow of a river will be in any given year, and even short term forecasts of spring flows based on known conditions such as accumulated snowpack and soil moisture are highly speculative, since weather conditions cannot be predicted more than a few days in advance. A period of unseasonably warm spring weather or a few days of heavy rain can render a short term forecast invalid. Predictions of stream flow over the long term are based on knowledge of stream flow in preceding years, and are stated in terms of the probability of a given rate of flow occurring in any one year, expressed as a per cent. Thus, we speak of flows, or floods, with a 2% chance, or one chance in 50 (1:50), of occurring in any one year. Such a flood is commonly referred to as a one in 50 year flood. This can be misleading, for while there is a high probability that such a flood will occur once in 50 years there is also the chance, although much less - in this case a 2% chance, that it will occur in any year.

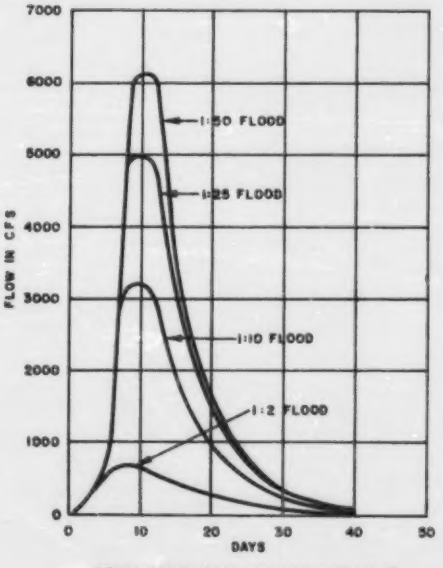
There are approximately 60 years of record for the Moose Jaw River upon which to base the probability of stream flow. Hydrographs, graphs which indicate the rate of stream flow in cubic feet per second at any time during a given period, were developed for floods with a probability of occurrence in any one year of 50% (1:2), 10% (1:10), 4% (1:25), 2% (1:50), 1% (1:100), 0.2% (1:500), and for the Probable Maximum Flood at stations above and below the city of Moose Jaw. The Probable Maximum Flood is defined as the most severe flood that may reasonably be expected to occur in the Basin, and for this study



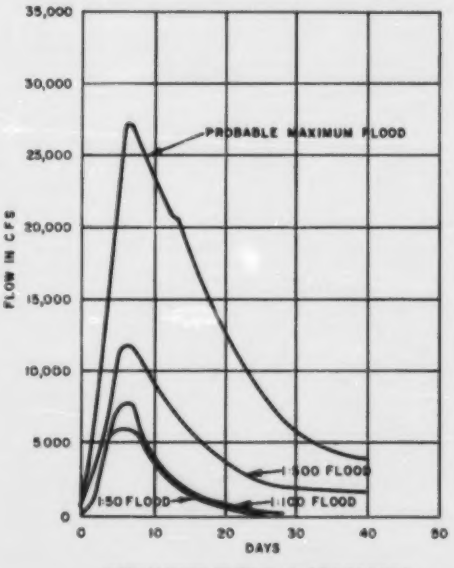
ESTIMATED FLOOD HYDROGRAPHS
OF MOOSE JAW RIVER AT BURDICK
(1:2, 1:10, 1:25, 1:50)



ESTIMATED FLOOD HYDROGRAPHS
OF MOOSE JAW RIVER AT BURDICK
(1:50, 1:100, 1:500 & PROBABLE MAXIMUM)



ESTIMATED FLOOD HYDROGRAPHS
OF MOOSE JAW RIVER ABOVE THUNDER CREEK
(1:2, 1:10 1:25, 1:50)



ESTIMATED FLOOD HYDROGRAPHS
OF MOOSE JAW RIVER ABOVE THUNDER CREEK
(1:50, 1:100, 1:500 & PROBABLE MAXIMUM)

FIGURE 3 : FLOOD HYDROGRAPHS

was considered to result from the maximum amount of run-off due to snowmelt combined with a severe rain storm. Since the capacity of the channel of the Moose Jaw River through the city of Moose Jaw is not adequate to contain flows greater than 3000 cubic feet per second, flows that exceed this rate result in overbank flow and flood conditions. The hydrographs, referred to as flood hydrographs, are shown in Figure 3.

As the rate of stream flow increases the water surface level rises; once the channel capacity of the stream is exceeded, water flows across the flood plain. The area of the flood plain that will be inundated at a given rate of flow can be determined from a knowledge of the surface level of the water and the topography of the flood plain. A computer model was used to determine the surface water level at different points along the river for open channel conditions, and this information was plotted on a map of the flood plain to indicate the land areas that would be inundated by floods of various frequencies. This map is shown as Figure 4. As can be seen on the map, the 10% (1:10) flow is almost completely contained within the river channel; the Probable Maximum Flood covers virtually the entire valley bottom. The topography of the flood plain is such that for a given flood an area close to the channel may be above water while areas further removed may be flooded.

For this study the flood plain is defined as the area that would be inundated by the Probable Maximum Flood. For the purposes of gathering data and considering management alternatives, the flood plain has been divided into seven areas identified as Kingsway Park, Agriculture South, Churchill Park, Wellesley Park, River Park, City Park, and Industrial. The boundaries of these areas are indicated in Figure 2.

Land use on the flood plain within the city of Moose Jaw is shown in Figure 5. Only 23% of the 745 acres of land on the flood

Photo by Brigden's Photo/Graphics - Flooding in Churchill Park in Moose Jaw during the Spring Flood of 1969

plain has been subjected to intensive development: 6% for residential use, 16% for commercial and industrial use, and 1% for institutional use. The remaining 77% of the flood plain, approximately 575 acres, is used for agriculture or recreation or is undeveloped open space.

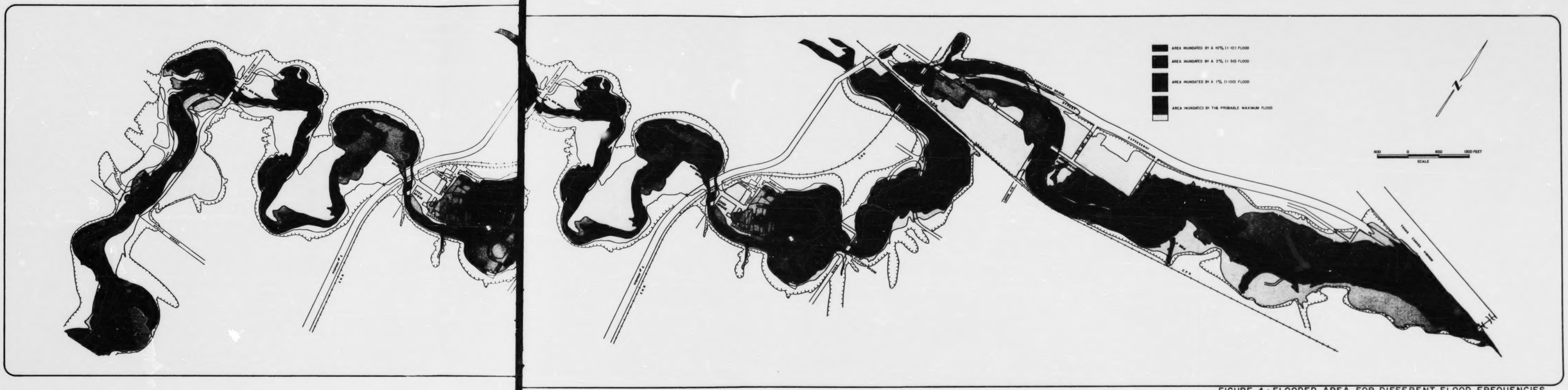

AREA INUNDATED BY A 10% (1 10) FLOOD
AREA INUNDATED BY A 2% (1 50) FLOOD
AREA INUNDATED BY A 1% (1 100) FLOOD
AREA INUNDATED BY THE PROBABLE MAXIMUM FLOOD
600 0 600 1200 FEET
SCALE

FIGURE 4 : FLOODED AREA FOR DIFFERENT FLOOD FREQUENCIES

TABLE 3: RESIDENTIAL OCCUPANCE OF THE FLOOD PLAIN

AREA	Residential Land Use		Residences		Resident Population[1]	
	Acres	% of Total	Number of Homes	% of Total	Number of Persons	% of Total
Kingsway Park	7.70	16.5	8	5.7	27	5.7
Agriculture South	-	-	3	2.1	10	2.1
Churchill Park	23.60	50.3	99	70.7	337	70.7
Wellesley Park	6.69	14.2	11	7.9	37	7.9
River Park[2]	7.47	16.0	9	6.4	31	6.4
Industrial	1.37	3.0	10	7.2	34	7.2
Total	46.83	100.0	140	100.0	476	100.0

[1]Estimated at 3.4 persons per household on the basis of Residential Data Survey conducted for this study in 1973 which obtained returns from 112 of 119 households surveyed.

[2]Includes one house in the adjacent sub-division of Pleasantview.

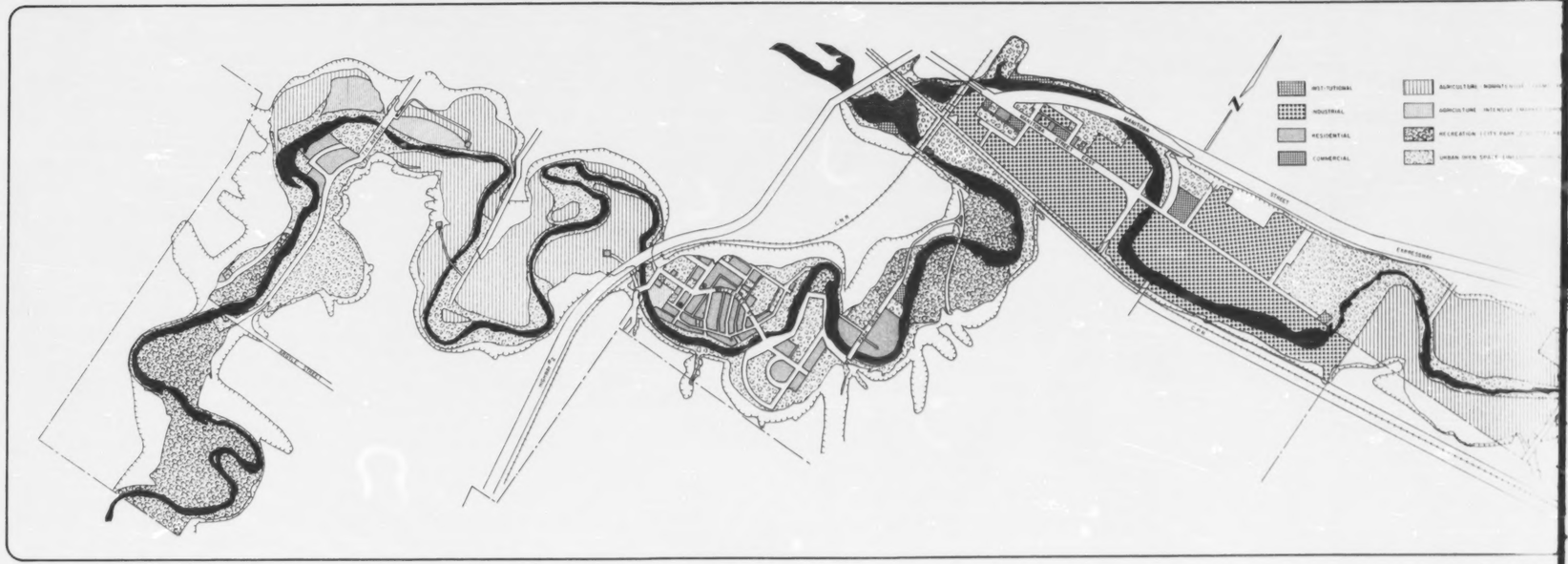
There are 140 residential buildings, housing approximately the same number of families, located on the 47 acres of land in residential use on the flood plain. The residential population of the flood plain has been estimated at 475 persons. Approximately 8% of these residents are retired adults and 38% are children of school age or younger.

There are four residential sub-divisions located almost entirely on the flood plain: Kingsway Park, Churchill Park, Wellesley Park, and River Park. There is also a scattering of residences in two other areas: Agriculture South and Industrial. Details concerning residential occupance of the flood plain are presented in Table 3.

Churchill Park is the largest and most intensively developed of the residential sub-divisions. It includes 50% of the land in residential use, 70% of the residential buildings and 70% of the population resident on the flood plain. Most commercial and industrial activity on the flood plain is concentrated in the Industrial area between the C.P.R. Dam and the Gulf Dam. There are three industrial establishments: an asphalt plant, a millwork and a chemical firm, and six commercial establishments in the Industrial area. There are large areas of land in agricultural use in the Industrial area between the Gulf Dam and the city limits and in the Agriculture South area. There are market gardens in Kingsway Park and Industrial, a tree nursery in Agriculture South, and florist's greenhouses in Churchill Park.

Approximately 60 per cent of the land on the flood plain is privately owned, including all of the residential, commercial and industrial land and most of the agricultural land. The city of Moose Jaw owns most of Wellesley Park and has large holdings in Kingsway Park, River Park, and the eastern part of the Industrial area. The city owns a portion of the land in the area designated as City Park and controls the remainder under a 999-year lease from the Canadian Pacific Railway. Most of the land owned or leased by the city is used for recreation or is undeveloped open space. There are strips of Crown-Owned right-of-way adjacent to the river in Churchill Park and Wellesley Park that could be critical for flood plain management. Land ownership on the flood plain is shown in Figure 6.

The areas that would be inundated by a 10% (1:10), 2% (1:50) and 1% (1:100) flood and by the Probable Maximum Flood are indicated in Figure 4. The floods that occurred in 1948 and in 1969 were approximately equal to the 2% (1:50) flood. Information concerning the number of residential or commercial and industrial establishments


INSTITUTIONAL
INDUSTRIAL
RESIDENTIAL
COMMERCIAL
AGRICULTURE - NONINTENSIVE (FARMS , PASTURE , ETC)
AGRICULTURE - INTENSIVE (MARKET GARDENS , NURSERIES)
RECREATION (CITY PARK , ZOO , CITY RECREATION)
URBAN OPEN SPACE (INCLUDING PUBLIC RESERVE)
SCALE

FIGUR

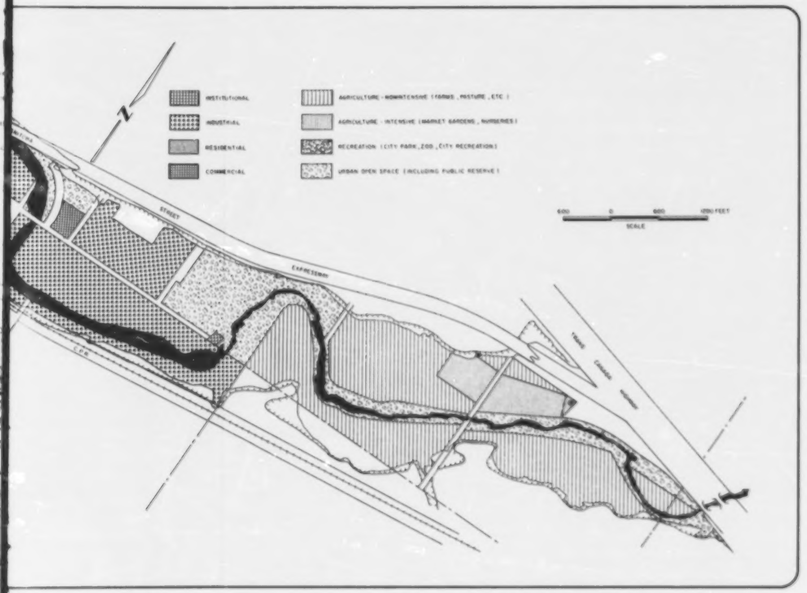


FIGURE 5 : LAND USE - 1973

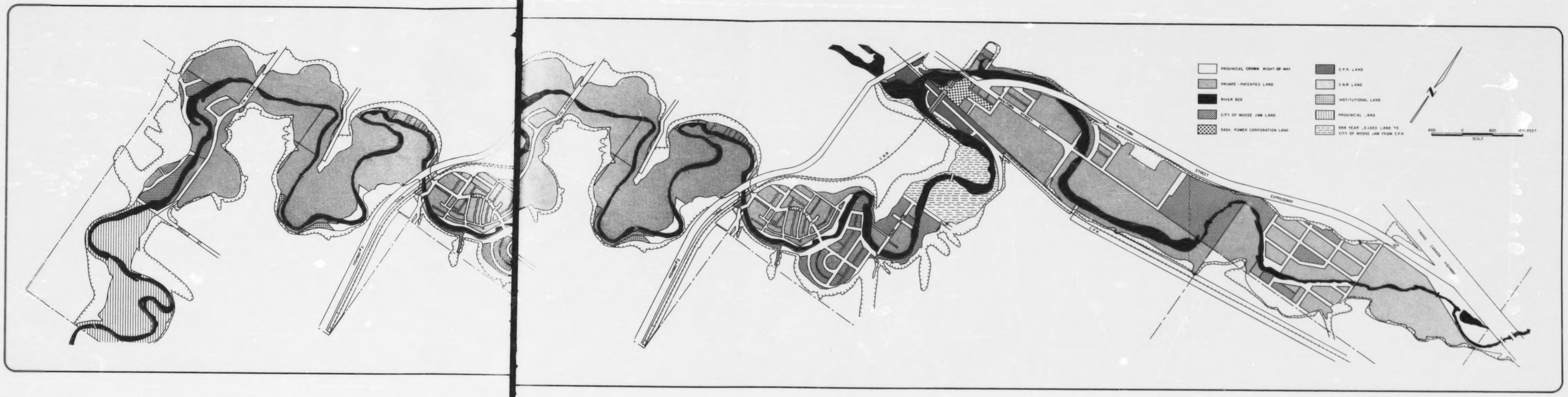


FIGURE 6 : LAND OWNERSHIP - 1973

affected by the 2% (1:50), 1% (1:100) and Probable Maximum Flood, estimates of the total damage that might be experienced as a result of these floods, and the average annual damage from all floods up to and including the Probable Maximum Flood is provided in Table 4. The data in this table were prepared on the basis of the hydrology studies and the flood plain inventory undertaken during the course of the study. Residential property damages were estimated using stage damage curves for different types of houses; commercial and industrial damages were estimated on the basis of interviews with managers or proprietors. Where estimates are based on data from previous years they were adjusted upward to reflect inflationary increases. Probability damage curves used to determine the average annual damages are included in Appendix 3.

Over one-half of the total estimated damage from a 2% (1:50) flood is damage to commercial and industrial establishments. One-third of the damage is to residential property. Two operations, a tree nursery in Agriculture South and the greenhouses in Churchill Park account for about one-half of the commercial and industrial damage. For floods of greater magnitude the portion of the damage attributable to residential property increases: 50% of the total for the 1% (1:100) flood and 70% of the total for the Probable Maximum Flood.

The most critically affected area is the residential subdivision of Churchill Park. Approximately one-half of the total damage from each flood shown in Table 4 is incurred in Churchill Park. Similarly, over one-half of the average annual damage from floods of all probabilities of occurrence is attributable to Churchill Park.

All of the costs of a flood are not revealed in property damage estimates and where property damage is presented in the aggregate the impact on individual property holders is concealed.

TABLE 4 : ESTIMATED POTENTIAL FLOOD DAMAGE

AREA	FLOOD	RESIDENTIAL BLDGS. AFFECTED		DAMAGE $	COMMERCIAL & INDUSTRIAL ESTABLISHMENTS AFFECTED	DAMAGE $	PUBLIC PROPERTY[1] DAMAGE $	TOTAL DAMAGE $	AVERAGE[4] ANNUAL DAMAGE $	PRESENT VALUE[6] OF AVERAGE ANNUAL DAMAGE $
		Total	Av.Annual							
Kingsway Park	2%(1:50)	8	.11	1,520	0	0	140	1,660	12	165
	1%(1:100)	8	.19	4,090	0	0	560	4,650	41	565
	PMF	8	.27	16,290	0	0	3,080	19,370	127	1,750
Agriculture South	2%(1:50)	1	.03	0[5]	1	21,240[5]	530	21,770	216	2,980
	1%(1:100)	1	.05	0	1	21,240	590	21,830	436	6,020
	PMF	3	.07	3,520	1	24,070	710	28,300	664	9,165
Churchill Park	2%(1:50)	41	1.13	23,060	2	13,740	3,160	39,960	1,128	15,570
	1%(1:100)	68	1.68	72,930	2	13,740	6,090	92,760	1,720	23,740
	PMF	99	2.46	327,580	2	24,320	17,760	369,660	3,292	45,435
Wellesley Park	2%(1:50)	4	.07	4,400	0	0	1,960	6,360	178	2,455
	1%(1:100)	8	.13	9,460	0	0	5,890	15,350	279	3,850
	PMF	11	.22	48,870	0	0	5,890	54,760	531	7,330
River Park[3]	2%(1:50)	7	.07	1,610	1	2,410	700	4,720	40	550
	1%(1:100)	9	.15	6,700	1	2,560	1,120	10,380	110	1,520
	PMF	9	.24	48,220	1	2,560	1,540	52,320	325	4,485
City Park	2%(1:50)	1	.01	680	0	0	1,490	2,170	13	180
	1%(1:100)	1	.02	2,990	0	0	3,020	6,010	58	800
	PMF	1	.03	3,740	0	0	3,510	7,250	120	1,655
Industrial	2%(1:50)	0	.00	0	3	16,990	4,110	21,110	196	2,705
	1%(1:100)	2	.02	300	4	26,900	10,480	37,680	484	6,680
	PMF	9	.06	29,580	9	74,320	23,780	127,680	1,040	14,355
Total	2%(1:50)	62	1.73	31,270	7	54,380	18,390[2]	104,040[2]	1,910	26,360
	1%(1:100)	97	2.51	96,470	8	64,440	34,050	194,960	3,442	47,505
	PMF	140	3.62	477,800	13	125,270	68,870	671,940	6,425	88,670

[1]Includes roads, sewage pumping stations, park washrooms.

[2]Total for each flood includes dams and bridges.

[3]Includes one residence in adjoining Pleasant View Sub-division.

[4]Average annual damage of all floods up to and including the flood indicated.

[5]Residential damage incurred at the tree nursery is included under Commercial and Industrial.

[6]The present value of average annual damages was calculated using a discount rate of 7% over a 50-year period.

This is particularly the case in residential areas where other costs and inconveniences are experienced, such as damage to yards and other buildings, disruption of utility services, evacuation of homes and time lost from work. When all of these factors are considered, Churchill Park remains as the most critically affected area. The most severely affected area within the sub-division lies between Lansing St. and Wellesley St., and in general, the severity decreases with distance from the Assiniboine Bridge. In Kingsway Park, Wellesley Park, and River Park costs are generally greatest for residences located closest to the river. The areas where the greatest residential costs are experienced are reasonably consistent with the area inundated by the 2% (1:50) flood, as indicated in Figure 4.

Another factor that must be considered when evaluating potential costs is the potential for loss of life due to floods. While there is no history of loss of life due to floods on the Moose Jaw River, there remains the possibility that such a disaster could occur.

2.2 ALTERNATIVE ADJUSTMENTS TO THE FLOOD HAZARD

One objective of the Supplementary Qu'Appelle Basin Agreement is to develop a flood plain management plan for the city of Moose Jaw that conforms to the long range planning objectives established by the study and the Qu'Appelle Framework Plan. The long term planning objectives for the Qu'Appelle that relate to flood plain management are to minimize property damage, economic and social disruption, and the threat of injury or loss of life from floods.

The Qu'Appelle Basin Study Board approached flood plain management in the Qu'Appelle with the philosophy of protecting existing development where it was economically feasible to do so, and leaving the undeveloped areas of the flood plain to the river. Similar views are held by city of Moose Jaw officials who, in recog-

nition of the flood threat and the value of the valley as park land, have expressed regret that parts of the area were developed in the past. This view is reflected in existing zoning by-laws, whereby parts of the flood plain in the areas referred to as Agriculture South and Kingsway Park downstream from the Wild Animal Park are zoned as Restricted Development Districts, and the city's active policy of acquiring land in Kingsway Park as it becomes available.

In examining various alternatives for flood plain management in Moose Jaw, both immediate and long range objectives were considered. They were:

(1) Immediate Planning Objectives:
Reduce property damage, economic and social disruption, and the threat of loss of life in developed areas on the flood plain.

(2) Long Range Planning Objectives:
Minimize the potential for property damage, economic and social disruption, and the threat of loss of life on the flood plain.

A number of alternative adjustments to the flood hazard were examined either singly or in combination. These adjustments may be classified as measures to control floods, measures to reduce potential for flood damage, and measures to modify the effects of floods.

The flood control measures considered, which include upstream storage, dykes, channel modification, and modification of control structures, are meant to prevent floods from occurring in certain areas. They are generally effective in achieving the immediate planning objectives in that they provide some degree of protection to existing development. These structural alternatives are costly, however, and tend to create a false sense of security, which frequently leads to more intensified occupance and development in flood

hazard areas and, consequently, increases the potential for flood damage.

Measures directed at reducing the potential for flood damage that were considered included land use change and land use controls. Land use alternatives are the most effective means of achieving the long range planning objectives. Land use change, in the sense of relocating existing development from the flood plain, is also an effective, though costly, means of achieving the immediate planning objectives.

Measures considered which are directed at modifying the damaging effects of floods included a flood forecasting, warning and emergency action program, and flood proofing. These measures tend to be most effective in combination with other alternatives, and are of benefit in achieving both immediate and long range objectives.

Six alternatives for upstream storage were considered. These are outlined briefly below and described in more detail in Appendix 2. Their locations are indicated in Figure 7. The control structures for these reservoirs were designed primarily for water conservation. Depending upon their operation, however, they can be used to some extent for flood control.

1. Lower Site Reservoir

   This alternative would involve the construction of an earth fill dam, 70 feet in height, on the Moose Jaw River at a point approximately 3 miles south of Moose Jaw in South 1/2 Section 10 and North-West 1/4 Section 3, Township 16, Range 26, W2. This dam would create a reservoir with a capacity of 64,000 acre-feet, and at the full supply level would flood an area of 4100 acres from the dam site to a point upstream from the confluence of Avonlea Creek, a few miles south of Rouleau. The estimated cost of this alternative is $6.0 million.

2. Upper Site Reservoir

   This alternative would involve the construction of an earth

fill dam, 32 feet in height, on the Moose Jaw River at a point near Tilney, approximately 10 miles south of Moose Jaw, in North 1/2 Section 9, Township 15, Range 25, W2. This dam would create a reservoir with a capacity of 20,000 acre-feet, and at the full supply level would flood an area of 2,200 acres from the dam site to a point upstream from the confluence of Avonlea Creek, a few miles south of Rouleau. The estimated cost of this alternative is $3.7 million.

3. Site X Reservoir

This alternative would involve the construction of an earth fill dam, 40 feet in height, on the Moose Jaw River at a point approximately one-half mile downstream from the Lower Site in South 1/2 Section 11, Township 16, Range 26, W2. This dam would create a reservoir with a capacity of 10,000 acre-feet, and at the full supply level would flood an area of 1,200 acres from the dam site to a point just south of Drinkwater in Section 30, Township 15, Range 23, W2. The estimated cost of this alternative is $2.6 million.

4. Modified Upper Site Reservoir

This alternative would involve the construction of an earth fill dam, 26 feet in height, on the Moose Jaw River at the same point as the Upper Site Dam. This dam would create a reservoir with a capacity of 10,000 acre-feet, and at the full supply level would flood an area of 1,400 acres from the dam site to a point just south of Rouleau in Section 34, Township 13, Range 22, W2. The estimated cost of this alternative is $3.0 million.

5. Summer Water Supply Reservoir

This alternative would involve the construction of a concrete and sheet pile dam, 15 to 20 feet in height, on the Moose Jaw River at a point approximately one mile upstream from the Lower Site in North-East 1/4 Section 3, Township 16, Range 26, W2.

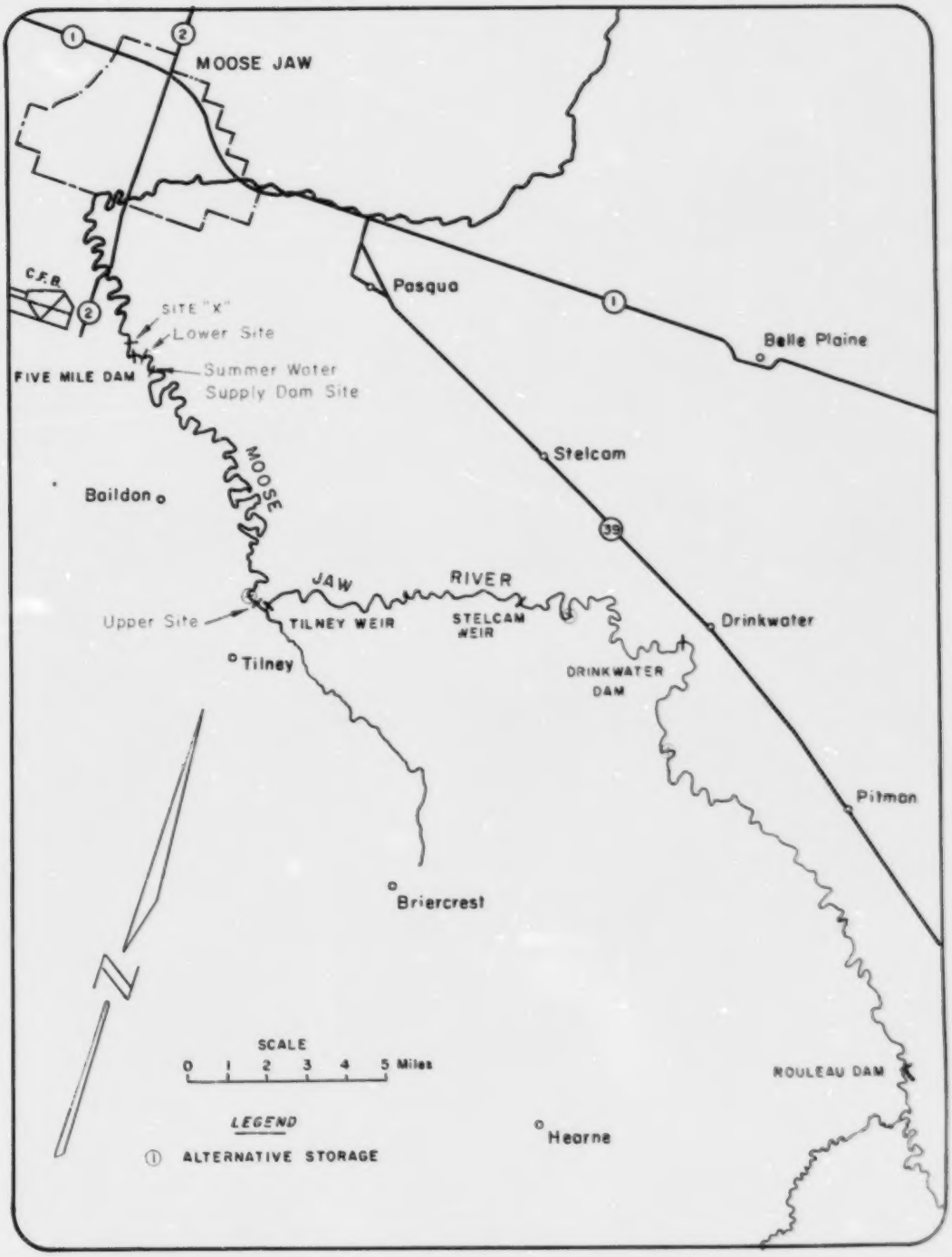
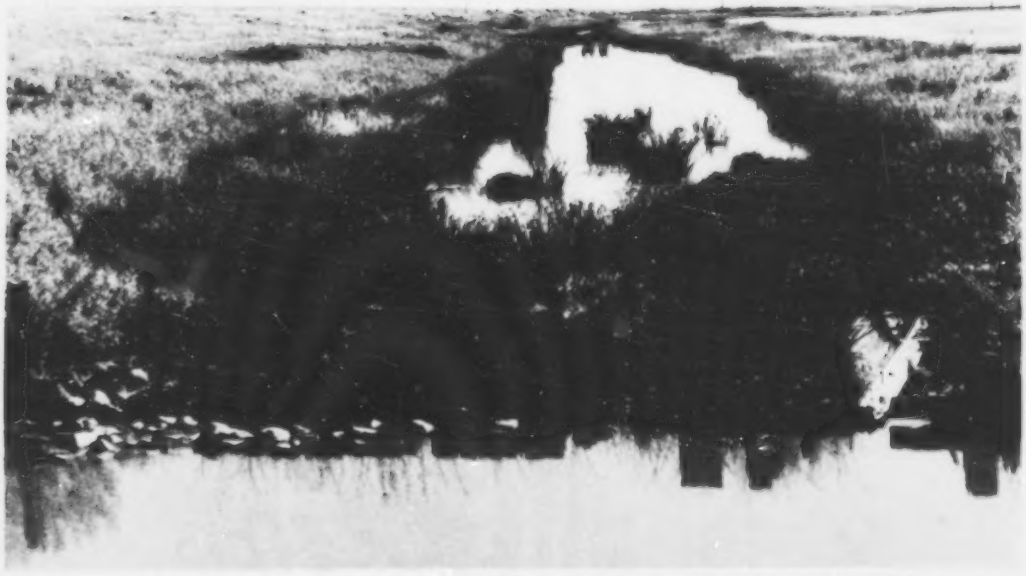
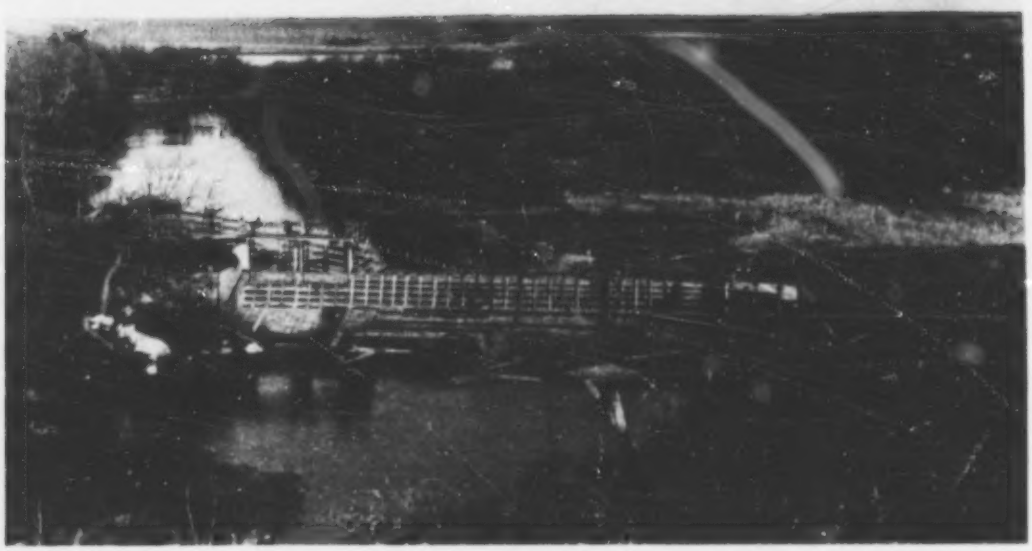


FIGURE 7 - ALTERNATIVES FOR UPSTREAM STORAGE



D.R.E.E. Photo - Rouleau Dam on the Moose Jaw River near Rouleau, Saskatchewan

D.R.E.E. Photo - Drinkwater Dam on the Moose Jaw River near Drinkwater, Saskatchewan



D.R.E.E. Photo - Five-Mile Dam on the Moose Jaw River near Moose Jaw, Saskatchewan

This dam would create a reservoir with a capacity of 2,700 acre-feet and at the full supply level would flood an area of 600 acres from the dam site to a point three miles east of Baildon in South-East 1/4 Section 29, Township 15, Range 25, W2. The estimated cost of this alternative is $886,000.

6. Small Reservoirs

This alternative would involve the reconstruction or alteration of five existing dams on the Moose Jaw River (Rouleau, Drinkwater, Stelcom, Tilney and 5-Mile) and the construction of dams at four other potential sites. These dams would create nine small reservoirs with a combined capacity totalling 2,200 acre-feet. The estimated cost of this alternative is $660,000.

A number of alternatives for dyking within the city were evaluated, and preliminary designs and cost estimates were prepared. The alternatives evaluated are outlined below and described in more

detail in Appendix 2. In general, dykes were designed with a 3:1 foreslope and a top width of eight feet. Where the available land was not sufficient to accommodate a dyke with a 3:1 foreslope, the dyke was designed with a vertical foreslope of sheet metal piling. The dykes were designed with aesthetic considerations in mind. It was therefore assumed that only land that would be occupied by the dyke would be cleared and the contractor would be limited to operating within this area, thus preserving the natural features of the area adjacent to the dyke. All dykes were assumed to be topsoiled and grassed and wherever possible were designed with a 6:1 backslope. The detrimental effects on private property would be minimized. The aesthetic constraints would result in increased costs. Drainage would be provided by extending storm sewers through the dykes and adding additional drains where required. All drains were designed with flap gates to prevent water from backing up through the drainage system during floods. In residential areas a four-foot buffer strip would separate the backslope toe of the dyke from the adjacent property line. In the Industrial area this buffer strip would be two feet wide. The top elevations of the dykes would be at the first even foot above the surface water elevation of the flood for which the dykes were designed, so that there would be from zero to one foot of freeboard throughout. There is no guarantee that the dykes would not be overtopped by a flood of a magnitude equal to or even less than that for which the dykes were designed if an obstruction such as an ice jam or debris accumulation occurred downstream and backed up the flood waters.

For Churchill Park, where the cost of a dyke designed to meet the aesthetic criteria was significant, and for Wellesley Park, dykes designed with no aesthetic constraints were also evaluated. These dykes were designed with 3:1 slopes throughout. The contractors' operations would not be constrained by the requirement to protect

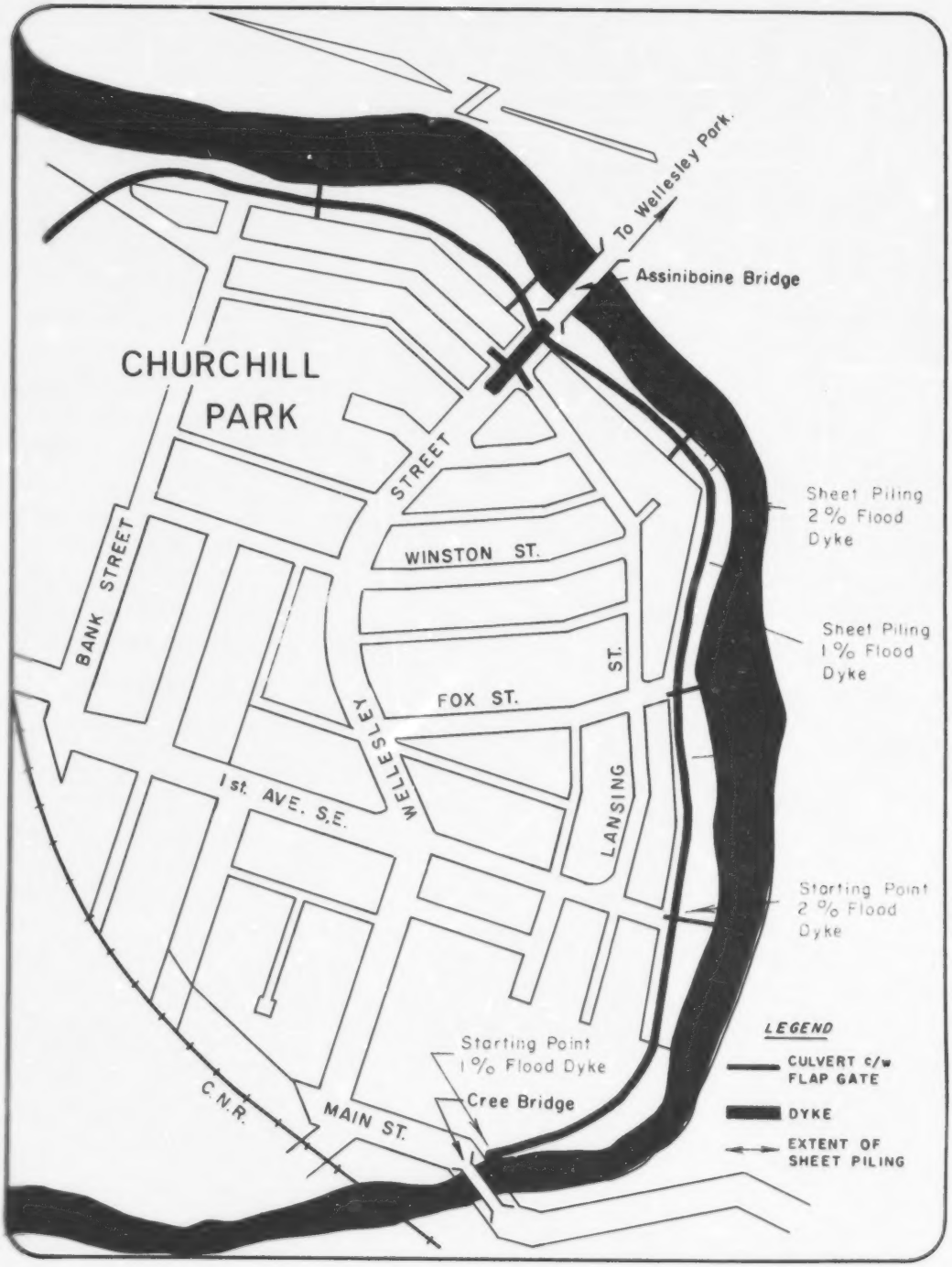


FIGURE 8 - CHURCHILL PARK DYKES

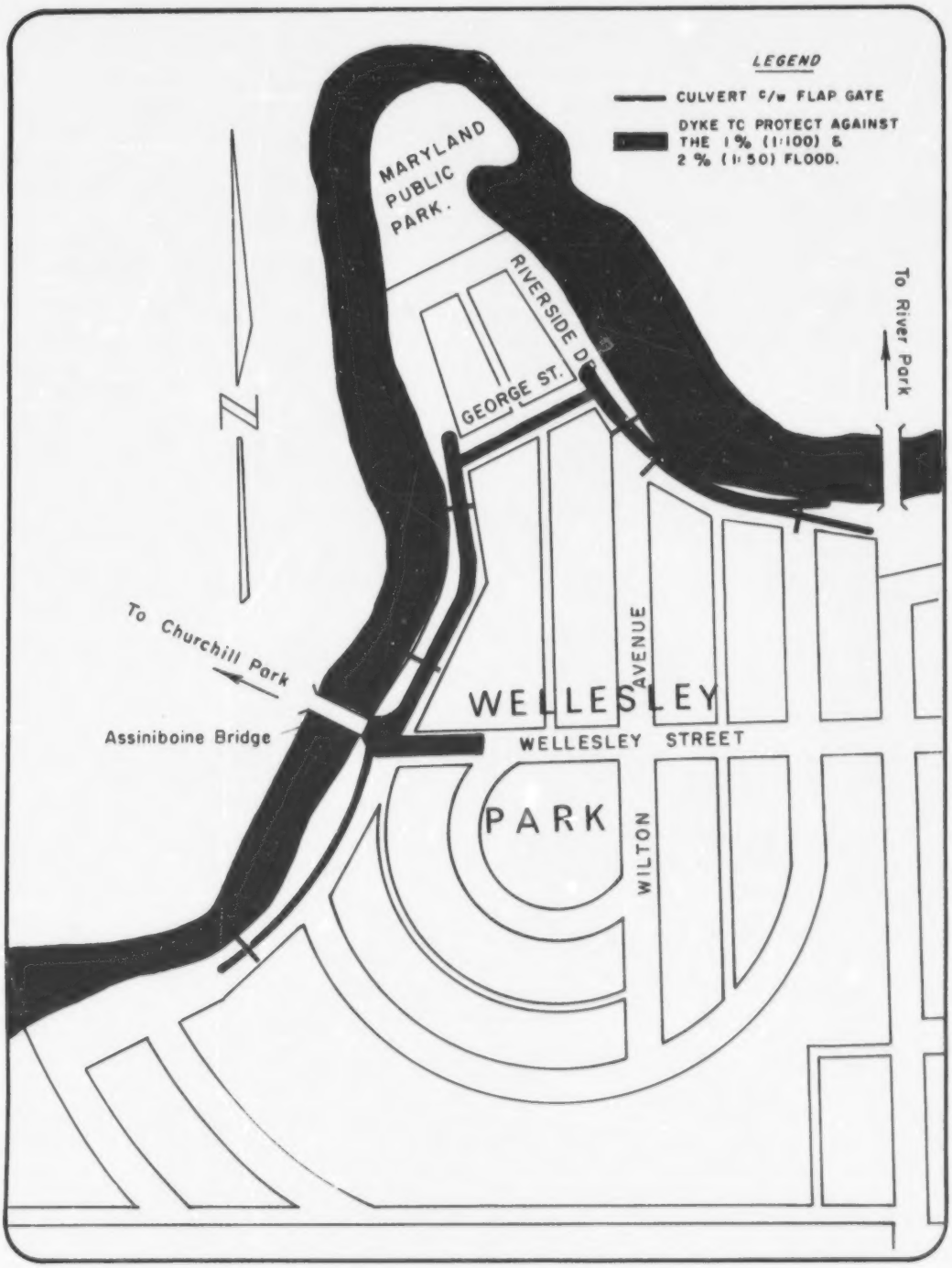


FIGURE 9 - WELLESLEY PARK DYKES

adjacent natural features and the detrimental effects on private property would be greater than in the case of the aesthetic design.

The dyking alternatives evaluated were as follows:

1. Churchill Park
   (i) Dyke to protect against the 1% (1:100) flood. The extent and location of this dyke are indicated in Figure 8. The cost is estimated at $138,500 for the aesthetic design and $69,700 for the non-aesthetic design.
   (ii) Dyke to protect against the 2% (1:50) flood. The extent and location of this dyke are indicated in Figure 8. The estimated cost is $48,400 for the aesthetic design and $31,800 for the non-aesthetic design. The 2% flood dyke would not protect the greenhouse and the house immediately downstream from the C.N.R. overpass.
2. Wellesley Park
   (i) Dyke to protect against the 1% (1:100) flood. The extent and location of this dyke are indicated in Figure 9. The cost is estimated at $25,350 for the aesthetic design and $23,200 for the non-aesthetic design.
   (ii) Dyke to protect against the 2% (1:50) flood. The extent and location of this dyke are indicated in Figure 9. The cost is estimated at $7,400 for the aesthetic design and $6,550 for the non-aesthetic design.
3. River Park
   (i) Dyke to protect against the 2% (1:50) flood. The extent and location of this dyke are indicated in Figure 10. The cost is estimated at $34,200. This

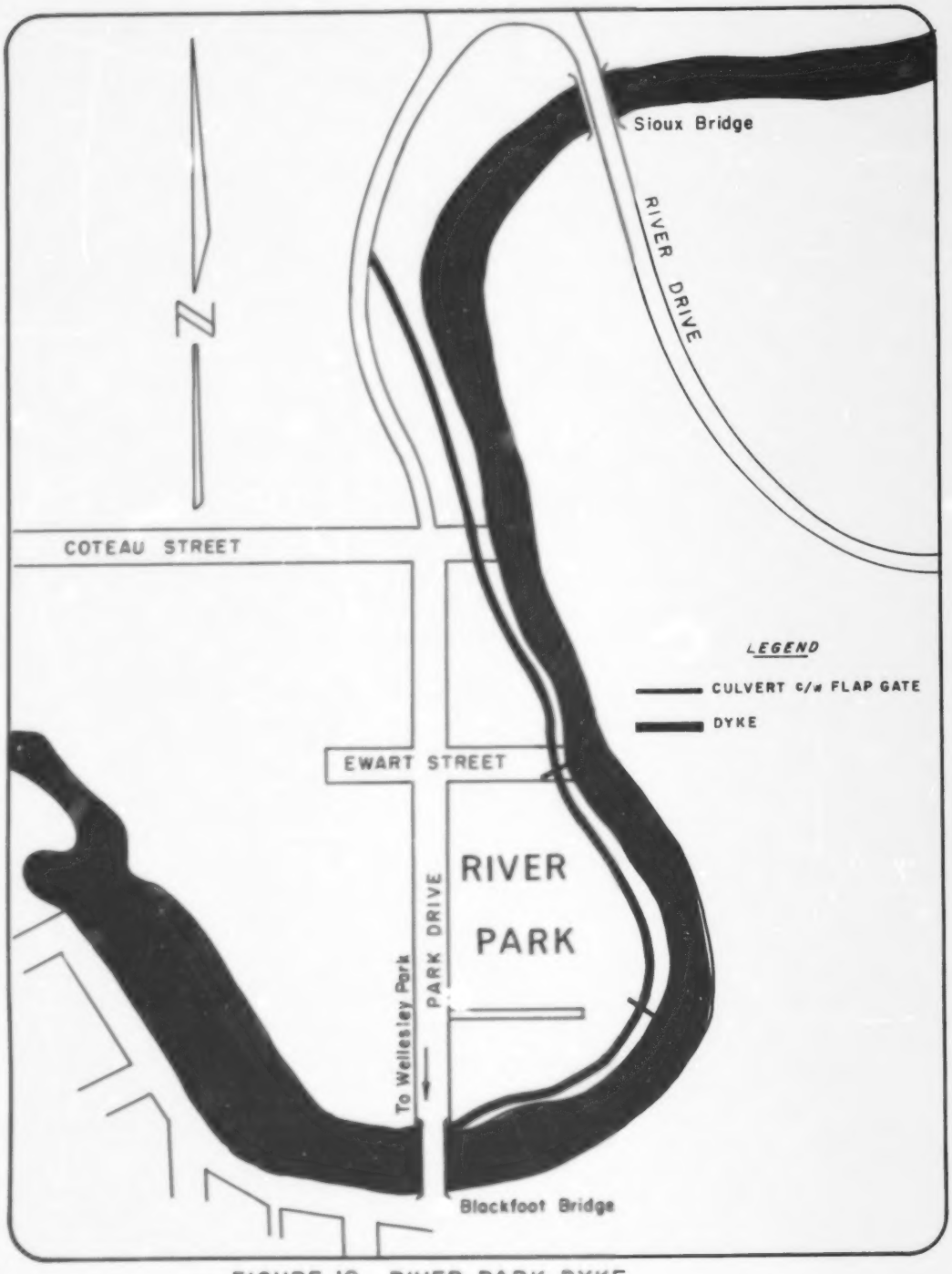


FIGURE 10 - RIVER PARK DYKE

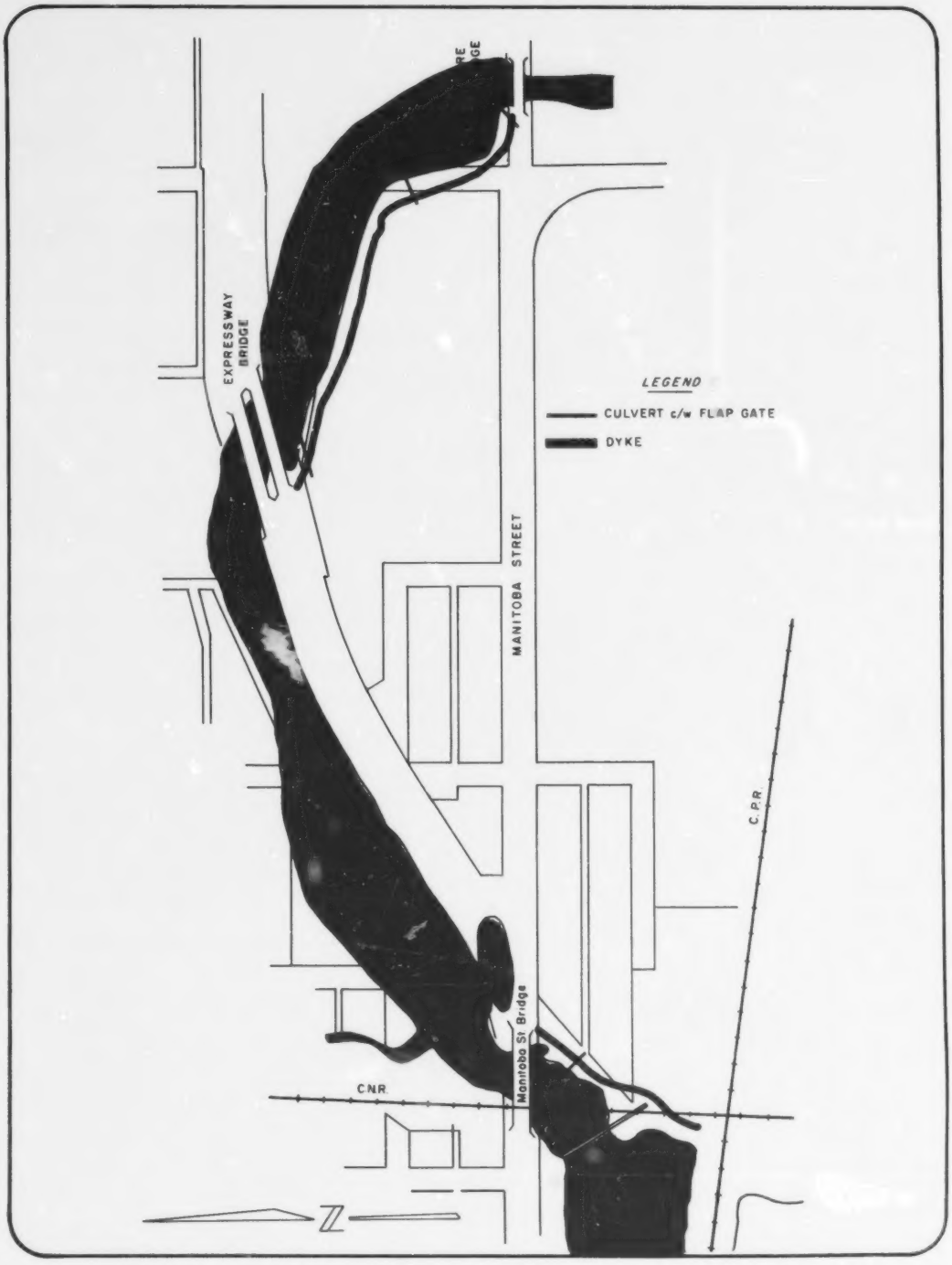


FIGURE II – DYKE FROM C.P.R. DAM TO HIGH PRESSURE DAM

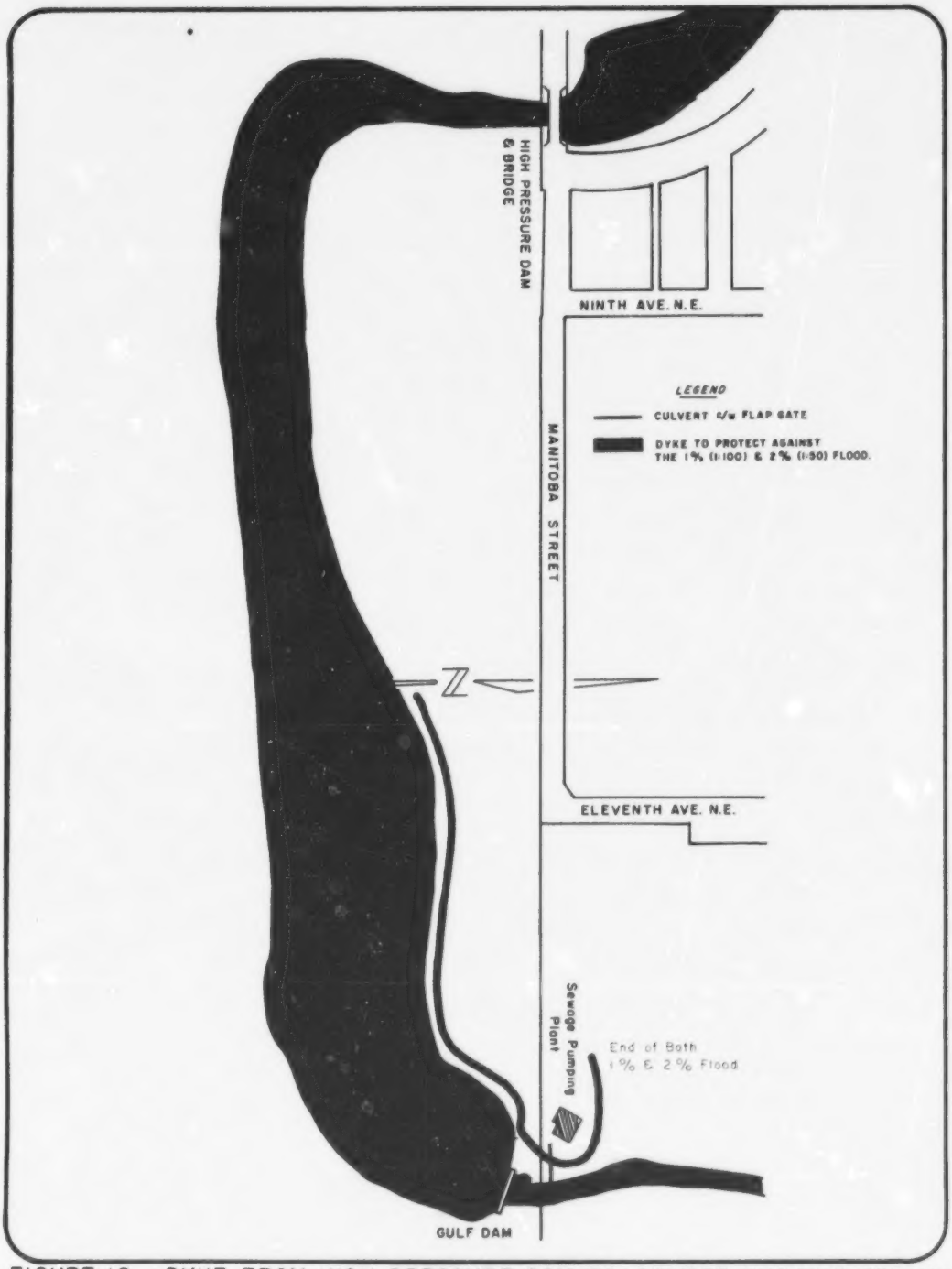

HIGH PRESSURE DAM & BRIDGE
NINTH AVE. N.E.
LEGEND
CULVERT c/w FLAP GATE
DYKE TO PROTECT AGAINST THE 1% (1:100) & 2% (1:50) FLOOD.
MANITOBA STREET
ELEVENTH AVE. N.E.
Sewage Pumping Plant
End of Both 1% & 2% Flood
GULF DAM

FIGURE 12 – DYKE FROM HIGH PRESSURE DAM TO SEWAGE PUMPING STATION

dyke would not protect the area upstream from the Blackfoot Bridge.

4. Industrial

A. C.P.R. Dam to High Pressure Dam

(i) Dyke to protect against the 1% (1:100) flood. The extent and location of this dyke are shown in Figure 11. The cost is estimated at $18,900.

(ii) Dyke to protect against the 2% (1:50) flood. The extent and location of this dyke are shown in Figure 11. The cost is estimated at $11,000.

The Manitoba St. Expressway forms a part of these dykes. At the interchange east of the Manitoba St. Bridge at Fourth Ave. N.E. the Expressway is one-half foot lower than the dyke designed to protect against the 1% (1:100) flood, which would necessitate emergency sandbagging at this location.

B. High Pressure Dam to Sewage Pumping Station

(i) Dyke to protect against the 1% (1:100) flood. This dyke would include the existing Gulf Dyke, which would require additional embankment. Its extent and location are shown in Figure 12. The cost is estimated at $11,700.

(ii) Dyke to protect against the 2% (1:50) flood. The extent and location of this dyke are shown in Figure 12. The cost is estimated at $1,700.

Dykes were not considered for Kingsway Park because their construction would necessitate removal of most of the houses which they would be intended to protect. The benefit from a dyke to protect the Wild Animal Park would be negligible and would destroy the natural vegetation important to the park setting.

There are a number of areas where the channel of the Moose

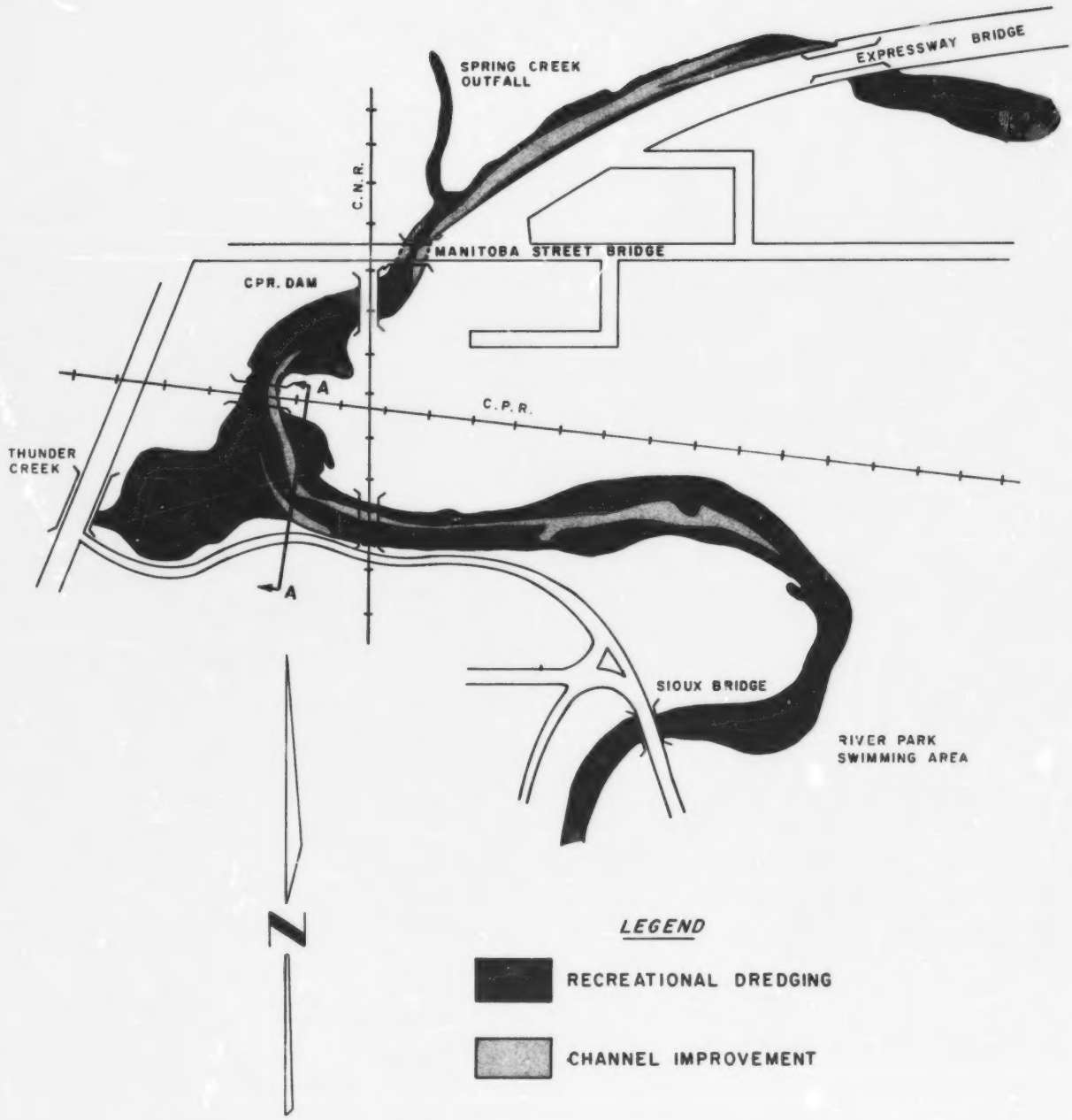


FIGURE 13- PRINCIPAL AREAS OF DREDGING

Jaw River could be modified to improve its carrying capacity. However, since the sedimentation studies indicate that the Moose Jaw River appears to be in equilibrium and little is known about the sediment contribution of the tributary streams, it was not possible to estimate the rate of re-deposition or to assess the long term effectiveness of channel modification.

The areas examined are briefly outlined below and described in more detail in Appendix 2. The location and extent of the areas considered for dredging are shown in Figure 13.

1. Dredge the channel from the C.P.R. Dam to a point 1100 ft. upstream from the C.N.R. Bridge in the City Park area. The cost is estimated at $18,200.
2. Remove debris and sediment in the area of the Spring Creek Outfall from the Manitoba St. Bridge to the Expressway Bridge. The cost is estimated at $14,900.
3. Remove the sediment deposit at the foot of Fox St. in Churchill Park. The cost is estimated at $2,500.
4. Remove a small mud and sand bar in the vicinity of Ewart St. in River Park. The cost is estimated at $800.

Consideration was given to modification of the control structures within the city to obtain flood control benefits. The only modifications that would be effective involve complete removal of the C.P.R., High Pressure, and Gulf Dams. Removal of these structures would have a significant effect in the Industrial area, but the effect would be negligible in the residential areas upstream. Removal of these structures would, of course, result in a virtually dry river channel through the city for most of the year. This is not consistent with the city's objective of maintaining stable water levels; and modifications to the Gulf Dam, which would be required to provide the same flood protection while maintaining the existing

ponding effect, would involve very high expenditures.

The cost of changing land use by purchase in developed areas was examined for the entire flood plain, for sub-divisions, and for selected areas which might be included as a package with other management alternatives. Preliminary estimates indicate that the cost of such a program for the entire flood plain would be about $3.1 million. The cost of the program in the four main residential areas would be: Kingsway Park, $150,000; Churchill Park, $1.8 million; Wellesley Park, $225,000; and River Park, $315,000. Considering only the most critically affected part of Churchill Park the cost would still be in excess of $1.0 million. This program is discussed in more detail in Appendix 4.

Land use control through zoning by-laws was examined as a means of reducing the potential for flood loss in the future. The city's existing land use zoning plan and by-laws were examined to determine the potential for changes in zoning. The current zoning map of Moose Jaw is shown in Figure 14.

The existing zoning plan does not take the flood hazard into account. The city could limit the potential for flood damage by implementing a revised zoning plan, based in part on the flood hazard areas identified in this study, that would regulate development in the flood plain.

The potential for a program that would incorporate flood forecasting, a flood warning network and emergency action procedures was considered. However, due to budget limitations no attempt was made to design or cost such a program.

Flood forecasts on the Moose Jaw River are prepared by the Saskatchewan Department of the Environment as part of their forecasting program for the Qu'Appelle River. Forecasts are usually available about a week before the flood crest reaches the city. However, any rapid change in weather patterns resulting in abnormally

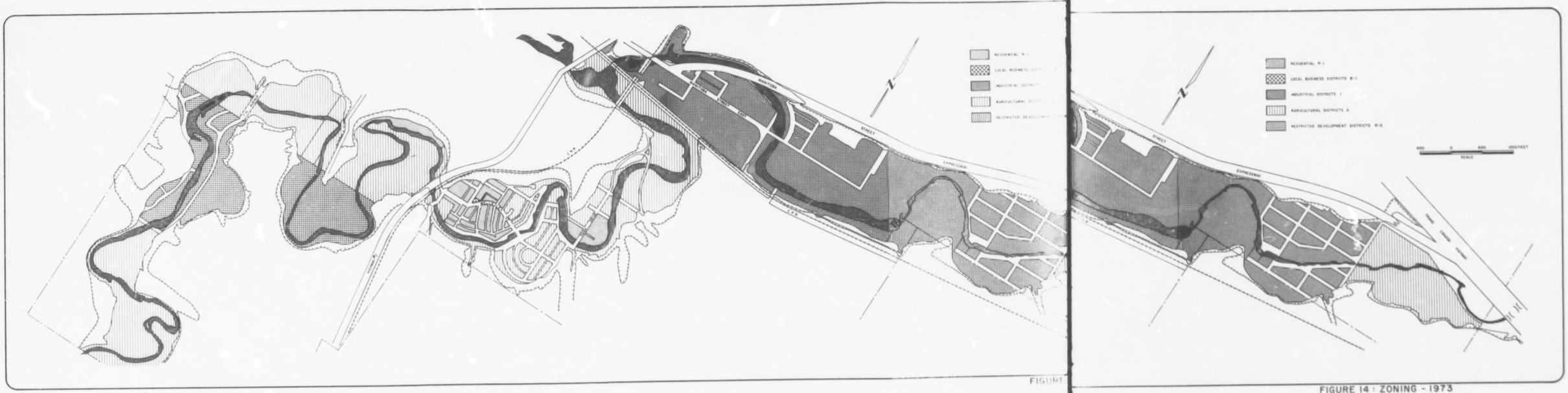


FIGURE 14 : ZONING - 1973

high temperatures or significant amounts of precipitation can reduce the forecast time. Since under the most ideal conditions and with the best forecasting techniques available forecasts will be less than perfect, there is need for an additional short range forecasting ability based on observation of streamflow levels immediately upstream from the city during high flow periods to determine when flood flows are imminent and to provide a few hours notice to flood plain occupants.

To be effective a flood warning network must extend from the forecaster to the occupants of the flood plain, and warnings must travel through this network with as little delay as possible. To meet these criteria there is a need for a carefully organized, highly flexible system which includes clearly defined responsibilities assigned to designated organizations, and a range of means of communication.

The replies to questions in the Residential Data Survey related to flood warning in 1969 revealed that flood warning time ranged from no warning at all to several days, and that warnings were received from a variety of sources, including city officials, news media, neighbours and personal observation. The indications are that the flood warning system in operation in Moose Jaw at the time of the 1969 flood could be improved upon.

Emergency measures include such precautions as temporary dyking along the river banks, evacuation of persons and property, sandbagging around houses, moving furniture and personal belongings to upper stories, closing sewer drains, and pumping out basements. In extreme circumstances rescue operations may be necessary. A discussion of emergency flood-proofing measures is included in Appendix 4. Fifty-six respondents to the Residential Data Survey reported that they had taken some sort of emergency precautions after receiving warning of the 1969 flood. They reported expenditures of $3,600 plus labour for these precautions, which included

sandbagging, moving furniture and effects to upper floors, closing off sewer drains and operating pumps to lower water levels in basements. The city of Moose Jaw supplied sand and sandbags for some sandbagging operations. Forty-six of the fifty-six respondents reported that the precautions that they took were effective in reducing flood damage. The total damage to homes and contents reported by respondents to the survey, 70% of whom were resident in the flood plain in 1969, was $16,000. The estimated potential damage to homes and contents from a 2% (1:50) flood is $27,000. These totals are not exactly comparable since responses were not received from all persons resident on the flood plain in 1969, and since the 1969 flood was of greater magnitude than a 1:50 flood. However, they suggest that the benefits from emergency measures are significantly greater than the costs.

Emergency measures may be implemented by individuals to protect their own property and by governments and other organizations, such as the Saskatchewan Power Corporation, to protect neighbourhoods, and public utilities and services. To have a maximum effect, emergency action must be planned in advance and executed according to plan under the direction and coordination of a central authority. Advanced planning requires a thorough knowledge of the flood hazard area, the measures that can be implemented to prevent flood damage and the resources that will be available to implement these measures.

Flood proofing of individual buildings is also considered an effective means of reducing flood damage. Some flood proofing measures are discussed in Appendix 4, but no attempt was made to examine the potential for flood proofing in any detail, or to estimate benefits or costs. Twenty respondents to the Residential Data Survey indicated that they had undertaken some form of flood proofing measures prior to the 1969 flood. These included building houses with higher points of entry, filling in lots, building retaining walls and

dykes, and sealing basement windows. These measures cost a total of $7,800. Sixteen of the twenty respondents reported that these measures proved effective in reducing damage during the 1969 flood; however, no estimates of damage reduction are available.

Photo by J. E. Glenn - Kingsway Dam in Moose Jaw

Photo by J. E. Glenn - The C.P.R. Dam in Moose Jaw

CHAPTER 3
WATER QUANTITY MANAGEMENT

3.1 WATER USE AND SUPPLY

Very little water is withdrawn from the Moose Jaw River for use within the city of Moose Jaw. In the past, the river served as a source of water for the C.P.R. and for industrial use, and the city was reliant upon the river as an auxiliary source of water for fire protection. At present the main value of the river is for recreation use and for its aesthetic appeal. The river meanders through large areas of park land and some attractive residential areas in the south-east part of the city. The four impoundments - the Kingsway, C.P.R., High Pressure, and Gulf Dams - create fairly extensive water surfaces throughout the length of the river within the city. The river has, at various times in the past, been used fairly intensively for swimming and boating. A bathing beach with a change house was developed in the City Park area immediately downstream from the Sioux Bridge in the late 1960's, but has since been closed due to poor water conditions. In 1972 the Saskatchewan Summer Games were held in Moose Jaw, and the canoeing events were staged on the Moose Jaw River upstream from the C.P.R. Dam.

Since, like most prairie streams, its water supply is almost entirely from surface run-off, the Moose Jaw River generally carries moderate to high flows during the period from mid-March to mid-June with little or no flow throughout the remainder of the year. During the latter period the water impounded by the reservoirs stagnates and the surface levels are reduced through evaporation and seepage. Sediment deposits have accumulated along the banks of the C.P.R. reservoir creating shallow water conditions near the shore. These

conditions promote heavy growths of bull rushes that detract from the aesthetic appeal and restrict the recreational use of the river in this area.

3.2 WATER QUANTITY MANAGEMENT ALTERNATIVES

One of the objectives specified in the Supplementary Qu'Appelle Basin Agreement is to develop a plan to maintain stable water levels in the Moose Jaw River in the city of Moose Jaw. At meetings with city officials it was determined that the city was most concerned with enhancing the aesthetic appeal and recreation potential of the river. For these reasons the city wishes to retain the four impoundments within the city limits, and would like to have these maintained at the full supply level. However, since the full supply level of the Gulf Reservoir exceeds the sill elevation of the High Pressure Dam by some three feet, the water level of the High Pressure Reservoir is controlled by the Gulf Dam. Thus, there are in effect only three impoundments at full supply level. The city would also like to have a continuous flow of water in the river. Thus, the water quantity objective was further defined as:

(1) To maintain the Kingsway, C.P.R., and Gulf Dams at full supply level.

(2) To provide a continuous flow of water in the Moose Jaw River through the city of Moose Jaw.

It was estimated that to replace the water lost from the four reservoirs in Moose Jaw due to consumptive use, evaporation and leakage through the structures, and thus to maintain the reservoirs at their full supply level, would require a minimum flow of one cubic foot per second. The condition of the C.P.R. and Gulf Dams is such that unless the structures are repaired there is a potential for greater leakage in future years.

To meet the water quantity management objectives requires that the supply of water available throughout the year be increased. This

Photo by J. E. Glenn - The High Pressure Dam in Moose Jaw. The De-Watered Gulf Reservoir and the Gulf Refinery Pipeline Crossing are in the Foreground.

Photo by J. E. Glenn - The Gulf Dam in Moose Jaw

could be achieved through upstream storage of spring runoff or through diversion from another river basin.

Six alternatives for upstream storage reservoirs on the Moose Jaw River were investigated. These alternatives are outlined briefly in Chapter Two and described in greater detail in Appendix 2.

A water supply study, using a computer model to simulate flows, was undertaken to determine the effect of the various reservoirs on flows through the city of Moose Jaw. It was determined that the guaranteed minimum mean monthly flow that could be delivered from the 64,000 acre-foot Lower Site Reservoir was 17 cubic feet per second. The guaranteed minimum mean monthly flow that could be delivered from the 20,000 acre-foot Upper Site Reservoir was 9 cubic feet per second. The guaranteed minimum mean monthly flow that could be delivered from either the Site X Reservoir or the Modified Upper Site Reservoir, each with a storage capacity of 10,000 acre-feet, was 5 cubic feet per second. The nine small reservoirs, with a combined storage capacity of 2,200 acre-feet, would not provide a measurable year round flow through the city of Moose Jaw.

The Summer Water Supply Reservoir was designed primarily to enhance the water supply in the river through the city during the summer months. This reservoir could be operated to maintain the full supply level in the impoundments and to provide some visible flow through the city. The rate of flow from the reservoir would be dependent upon the length of the operating season. For example, the reservoir could provide a continuous flow of up to 17 cubic feet per second during July and August or it could provide a continuous flow of 8 cubic feet per second from the beginning of June to the end of September. Alternatively, the reservoir could be operated to provide a complete refill of all impoundments within the city on two occasions during the summer months. If required, the reservoir could be operated to provide a combination of continuous and surge flows. Analysis indicated that the quantities of water needed to provide these flows would be available in all but three of the sixty years of record.

Any controlled storage within five miles upstream of the city that would provide 200 acre-feet of water after allowance for evaporation, seepage, and channel losses could serve to enhance water

supply in the river within the city. Depending upon the size of the reservoir, streamflow could be made available for varying periods during the summer season. Operating flexibility would increase with reservoir size as indicated by the following examples.

A 200 acre-foot reservoir could provide a flow of about 1 cubic foot per second for two months. This is approximately twice the flow entering the river as effluent from CFB over the same period. If the Kingsway and C.P.R. Dams were at the full supply level at the end of June, they could be maintained at that level for July and August.

A 500 acre-foot reservoir could provide a flow of about 1 cubic foot per second for five months or about 3 cubic feet per second for two months. This flow could provide enough water to fill the Kingsway and C.P.R. Reservoirs to the full supply level at the end of June and maintain flows at this level during July and August. Alternatively, it could permit the C.P.R. Reservoir to be drained and refilled once during the summer.

A 1000 acre-foot reservoir could provide about 3 cubic feet per second for five months or 8 cubic feet per second for two months. It could provide enough water to fill the Kingsway and C.P.R. Reservoirs at the end of June, permit the C.P.R. Reservoir to be drained and refilled once during the summer, and still maintain a flow of approximately 3 cubic feet per second during the months of July and August.

Information on the upstream storage alternatives as they relate to water supply is provided in Table 5. During the course of the upstream storage investigations it was established that the cost of mainstream storage is approximately $300-$400 per acre-foot, depending upon reservoir size.

With a view to increasing the usable water surface area and enhancing the recreational and aesthetic value of the river bank, consideration was given to dredging portions of the shoreline of the C.P.R. Reservoir from the C.P.R. Dam to a point immediately downstream from the swimming area in City Park. The location and extent of the area to be dredged is indicated in Figure 13 and is described

in more detail in Appendix 2. The cost of this dredging operation has been estimated at $22,800.

One project investigated by the Saskatchewan-Nelson Basin Board in their report, "Water Supply for the Saskatchewan-Nelson Basin", was diversion of water from Lake Diefenbaker to the Souris River Basin via the Qu'Appelle River. A canal would be required to carry water from the Qu'Appelle to the Souris. A secondary canal to divert water from the main canal into the Moose Jaw River was also examined. Estimated costs of the secondary canal were $2.2 million to convey 75 cubic feet per second, or $2.7 million to convey 200 cubic feet per second. Any consideration of this secondary canal would, of course, be contingent upon development of the main canal to the Souris. This proposal was not considered in this study, but is mentioned for future consideration as a possible alternative for providing increased flows in the Moose Jaw River.

TABLE 5: UPSTREAM STORAGE ALTERNATIVES - WATER SUPPLY

Alternative	Storage Capacity (Acre-Feet)	Minimum Mean Monthly Flow (cfs)	Maximum Drawdown From FSL (feet)	Percentage[1] of Years Drawdown Exceeds 3.5 ft. (%)	Cost ($)
Lower Site Reservoir	64,000	17	29	50	6.0 mil
Upper Site Reservoir	20,000	9	12	60	3.7 mil
Site X Reservoir	10,000	5	*	*	2.6 mil
Modified Upper Site Reservoir	10,000	5	*	*	3.0 mil
Summer Water Supply Reservoir	2,700	17[2]	*	*	886,000
Nine Small Reservoirs	2,200	0	*	*	660,000

[1]3.5 ft. is the maximum acceptable drawdown if the reservoir is to be used for recreation.

[2]For July and August only, or eight cfs continuously for four months.

*Not determined.

CHAPTER 4
WATER QUALITY MANAGEMENT

4.1 WATER USE AND WATER QUALITY

There is very little withdrawal or consumptive use of water from the Moose Jaw River within the city of Moose Jaw. The main use of the river is for recreation and for its aesthetic value. There are large tracts of open space and developed recreation land in the valley adjacent to the river, including the Regional Wild Animal Park and a municipally-owned tent and trailer park. The main eastern approach to the city from the Trans-Canada Highway follows the river valley and within the city it runs adjacent to the river and crosses it at two points. There is some potential for swimming and boating in the river, and in the past there was some fairly intensive use of the river for these purposes. A municipal beach with a change house and playground was developed immediately downstream from the Sioux Bridge in the late 1960's, but was subsequently closed at the order of city public health officials due to the hazardous quality of the water.

The most obvious water quality problem within the city is the massive algal and weed growths that occur in the impoundments along the river. These render the river aesthetically unattractive and limit its use for recreation purposes. Other problems relate to the sporadic occurrence of coliform and fecal coliform bacteria, which indicate a potential health hazard, and the presence of various chemicals and other foreign substances harmful to aquatic life.

As in most prairie streams, the algae and weeds in the Moose Jaw River are due to the presence of an over-abundance of the nutrients phosphorus, nitrogen, and carbon, which support their growth. The

TABLE 6 : WATER QUALITY DATA - SELECTED STATIONS
MOOSE JAW RIVER
MEDIAN VALUES FOR AUGUST ,1972

	Phosphorus mg/l	Nitrogen mg/l	Total Organic Carbon mg/l	B.O.D. mg/l	pH	Turbidity (Jackson Units)	D.O. mg/l	Color (APHA)	Coliforms[2] per 100 ml	Fecal Coliforms[2] per 100 ml
Near Rouleau	.14	1.51	13	4.5	7.7	45	6.4	30	314	73
Above CFB	.11	1.65	19	4.8	8.3	42	7.8	40	1,400	293
Below CFB	2.20	8.37	22	12.3	8.9	23	20.5	-	803	77
At Wild Animal Park	.61	2.95	20	12.8	9.2	37	12.6	50	462	137
Below Kingsway Dam	.38	3.24	21	10.6	8.9	33	11.4	50	1,410	79
At Sioux Bridge	.22	3.01	21	10.1	8.7	31	7.8	60	12,800	917
C.P.R. Dam	.21	2.38	22	10.7	8.5	21	9.0	50	26,300	1,060
High Pressure Dam	.35	2.44	26	8.1	8.6	18	6.6	30	950	77
Below City Outfall	4.30	17.62	51	40.5	8.2	28	10.2	160	101,000	7,590
Near City Limits	4.40	15.49	42	21.0	8.1	26	4.2	100	13,400	230

[1]Mean monthly flow for August 1972: (a) Above the city of Moose Jaw (Station No. 05JE001) 0.55 cfs
(b) Below the city of Moose Jaw (Station No. 05JE006) 9.0 cfs

[2]Geometric mean values for August 1972

minimum concentrations of phosphorus and nitrogen generally believed to be adequate to support algal growth in surface water are 0.03 milligrams per litre (mg/l) phosphorus as PO_4, and 0.40 mg/l nitrogen. Table 6 shows median values for certain critical water quality parameters at selected stations on the Moose Jaw River for the month of August, 1972. More complete water quality data from the sampling and analysis program conducted for this study are included in Appendix 5.

The nutrient concentrations in the upper reaches of the river are adequate to support massive algal and weed growth in impoundments, backwaters, and along shorelines. Just above the Moose Jaw city limits the nutrient load in the river is increased by the effluent from the Canadian Forces Base treatment facility. Given the normal low flow conditions of the stream and the impoundments on the river within the city, a nutrient load of this magnitude promotes algal growth and causes odour problems in Moose Jaw.

Immediately downstream from the Gulf Dam the nutrient load in the river is further enriched with effluent from the city of Moose Jaw sewage treatment facilities. This effluent further increases the nutrient concentrations in the river, seriously depletes dissolved oxygen and causes large fluctuations in pH values.

As indicated in Table 6, the nutrient concentrations in the river within the city during the month of August, 1972 far exceeded those generally believed to be adequate to support algal growth.

On an annual basis estimates indicate that run-off from above the city accounts for 67%, the Canadian Forces Base effluent for 1%, Thunder Creek for 5%, Moose Jaw lagoon effluent for 21%, and other direct run-off for about 6% of the total nitrogen and phosphorus input to the system. The nutrient loading data indicated that for the fall, however, when natural flows are minimal, the contributions were 80% from Moose Jaw effluent, 20% from Canadian Forces Base effluent, and less than 1% from run-off. While 1% from run-off appears to be a relatively small percentage of the total nutrient loading, the quan-

tities of nutrient appear adequate to support massive algal growth.

Unfortunately, data on coliform and fecal coliform bacteria was very erratic. Further investigation will be required before any meaningful conclusions can be drawn.

Samples of bottom sediments at various locations within the city indicated the presence of insecticides, oil and minor elements, such as copper, lead, zinc, and mercury, in concentrations sufficient to be harmful to aquatic life. The results of the sediment analysis are presented in detail in Appendix 5.

In addition to being a significant contributor of nutrients to the Moose Jaw River, the effluent from the Canadian Forces Base frequently includes greater amounts of organic material than can be assimilated by the river system. Effluent from the Base is chlorinated, which generally ensures that it is of acceptable bacteriological quality for discharge.

The city of Moose Jaw sewage treatment facility, another major source of nutrients, also discharges significant amounts of algae from its lagoons during the summer months. The algae causes diurnal variations in the dissolved oxygen content of the river water, and degrades the aesthetic quality of the river downstream from the outfall.

Another potential source of pollutants in the Moose Jaw River is run-off from the Canadian Pacific Railway car cleaning operation, located on a permeable cinder fill adjacent to Thunder Creek. Above normal amounts of calcium, sodium, potassium, sulphate, and chloride were found in samples of run-off water from this area.

4.2 WATER QUALITY MANAGEMENT ALTERNATIVES

An objective of the Supplementary Qu'Appelle Agreement is to develop a plan to reduce water pollution in the Moose Jaw River in the city of Moose Jaw. The Qu'Appelle Basin Study Board has recommended that specific objectives for water quality be established for

the surface waters of the Qu'Appelle Basin. The Board further stated that the Specific Surface Water Quality Objectives published by the province of Saskatchewan should be adopted until more precise, specific objectives are developed. These objectives, as outlined in Table 7, were adopted as water quality planning objectives for the Moose Jaw River.

A number of management alternatives were considered that would contribute to bringing the quality of water in the Moose Jaw River up to the objectives presented in Table 7.

Tertiary treatment of sewage to decrease phosphorus loading was recommended for the Canadian Forces Base and the city of Moose Jaw in the report of the Qu'Appelle Basin Study Board. However, unless treatment for the complete removal of phosphorus was undertaken at the Canadian Forces Base the amount of phosphorus discharged into the river above Moose Jaw would still be sufficient to support massive algal growth in impoundments. Transporting the sewage from CFB to the Moose Jaw treatment facilities for discharge below the Gulf Dam would eliminate this source of nutrients above the city. Since

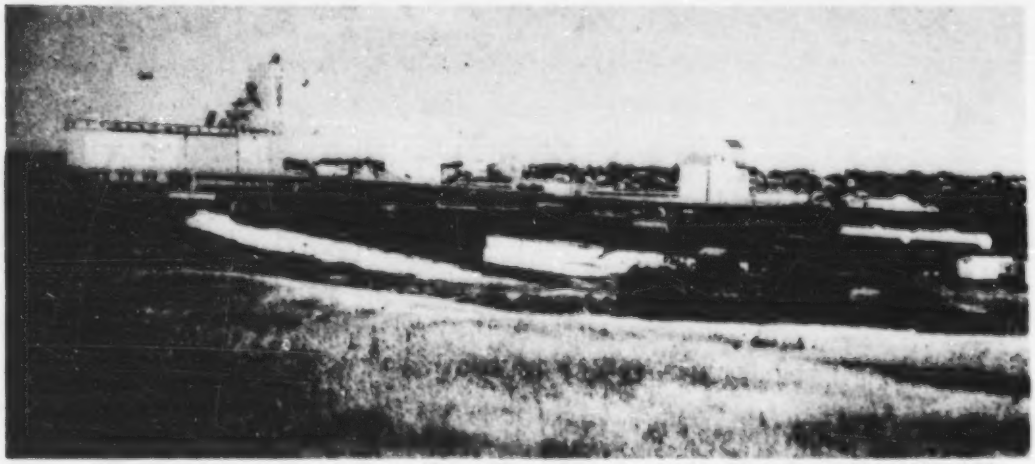


Photo by J. E. Glenn - Car Cleaning Area in the Canadian Pacific Railway's Moose Jaw Yards. The South Bank of Thunder Creek is in the Foreground.

TABLE 7 : SPECIFIC SURFACE WATER QUALITY OBJECTIVES

Parameter	Objectives
1. Bacteriology (Coliform Group)	(a) In waters to be withdrawn for treatment and distribution as a notable supply or used for outdoor recreation other than direct contact, at least 90 per cent of the samples (not less than five samples in any consecutive 30-day period) should have a total coliform density of less than 5,000 per 100 ml and a fecal coliform density of less than 1,000 per 100 ml. (The Maximum Permissible Limit of total coliform organisms in a single sample shall be determined by the Commission based on the type and degree of pollution and other local conditions existing within the watershed.) (b) In waters used for direct contact recreation or vegetable crop irrigation the geometric mean of not less than five samples taken over not more than a 30-day period should not exceed 1,000 per 100 ml total coliforms, nor 200 per 100 ml fecal coliforms, nor exceed these numbers in more than 20 per cent of the samples examined during any month, nor exceed 2,400 per 100 ml total coliforms on any day.
2. Dissolved Oxygen	A minimum of five mg/1 at any time.
3. Biochemical Oxygen Demand	Dependent on the assimilative capacity of the receiving water. The BOD must not exceed a limit which would create a dissolved oxygen content of less than five mg/1.
4. Suspended Solids	Not to be increased by more than 10 mg/1 over background value.
5. pH	To be in the range of 6.5 to 8.5 pH units but not altered by more than 0.5 pH units from background value.
6. Temperature	Not to be increased by more than 3°C above ambient water temperature.
7. Odour	The cold (20°C) threshold odour number not to exceed eight.
8. Colour	Not to be increased more than 30 colour units above natural value.
9. Turbidity	Not to exceed more than 25 Jackson units over natural turbidity.
10. Organic Chemicals	

Constituent	Maximum Concentration (mg/1)
Carbon Chloroform Extract (CCE) (includes Carbon Alcohol Extract)	0.2
Methyl Mercaptan	0.05
Methylene Blue Active Substances	0.5
Oil and Grease	substantially absent no irridescent sheen
Phenolics	0.005
Resin Acids	0.1

Pesticides	To provide reasonably safe concentrations of these materials in receiving waters an application shall not exceed 1/100 of the 48-hour TL_m. Persistent insecticides such as DDT, Aldrin, Dieldrin, Endrin, Heptachlor should not be used on or near surface waters.

11. Inorganic Chemcials

Constituent	Maximum Concentration (mg/1)
Boron	0.5
Copper	0.02
Fluoride	1.5
Iron	0.3
Manganese	0.05
*Nitrogen (Total Inorganic and Organic)	1.0
*Phosphorus as PO_4 (Total Inorganic and Organic)	0.15
Sodium (as per cent of cations)	between 30 and 75
Sulphide	0.05
Zinc	0.05

* These criteria are presently under study and may require adjusting according to naturally occurring concentrations or conditions.

NOTE: The predominant cations of sodium, calcium and magnesium and anions of sulphate, chloride and bicarbonate are too variable in the natural water quality state to attempt to define limits. Nevertheless, in order to prevent impairment of water quality, where effluents containing these ions are discharged to a water body the permissible concentration will be determined by the Commission in accordance with existing quality and use.

12. Toxic Chemicals

Constituent	Maximum Concentration (mg/1)
Arsenic	0.01
Barium	1.0
Cadmium	0.01
Chromium	0.05
Cyanide	0.01
Lead	0.05
Mercury	0.0001
Selenium	0.01
Silver	0.05

13. Radioactivity — Gross Beta not to exceed 1,000 pCi/1.
Radium 226 not to exceed three pCi/1.
Strontium 90 not to exceed 10 pCi/1.

14. Unspecified Substances — Substances not specified herein should not exceed values which are considered to be deleterious for the most critical use as established by the Commission.

TABLE 8 : NUTRIENT CONCENTRATIONS AT VARIOUS FLOWS MOOSE JAW RIVER

PHOSPHORUS CONCENTRATIONS (mg/l)			
Flow (cfs)	Natural[2]	Below CFB	Below M.J. Lagoon
1	0.14	2.20	4.30
9	0.14	0.43	1.67
17	0.14	0.29	1.06
25	0.14	0.25	0.80
50	0.14	0.19	0.48
100	0.14	0.17	0.32

NITROGEN CONCENTRATIONS (mg/l)			
Flow (cfs)	Natural[2]	Below CFB	Below M.J. Lagoon
1	1.51	8.37	17.62
9	1.51	2.47	7.35
17	1.51	2.02	5.01
25	1.51	1.86	4.01
50	1.51	1.69	2.83
100	1.51	1.60	2.19

CARBON CONCENTRATIONS			
Flow (cfs)	Natural[2]	Below CFB	Below M.J. Lagoon
1	18	22.0	51.0
9	18	18.6	29.0
17	18	18.3	24.6
25	18	18.2	22.7
50	18	18.1	20.5
100	18	18.1	19.3

[1]Assumes no change in nutrient concentrations due to unstream reservoirs.

[2]August 1972 values - see Table 6.

these measures are under consideration by the federal and provincial governments, no attempt was made to evaluate them in this study.

Augmentation of flows in the Moose Jaw River from upstream storage was considered. Studies of upstream reservoirs for water supply purposes indicated that the greatest guaranteed minimum flow that could be provided from the reservoir sites examined was 17 cubic feet per second. The effects of this and even greater flows on nutrient concentrations in the Moose Jaw River are summarized in Table 8. It is apparent that augmenting flows through Moose Jaw with water stored upstream in the Moose Jaw River would not reduce the nutrient concentrations sufficiently to prevent massive algal growth in the impoundments in the city.

Experience in other areas suggests that algae and aquatic weeds can be controlled effectively with chemicals, and mechanical harvesters can be used to keep impoundments free of weeds. The possibility of using these methods in Moose Jaw was examined.

Consideration was also given to the removal of all structures that impound water within the city. The nutrient concentrations in the river when it reaches the city are sufficient to support algae. Impounding these waters promotes ideal conditions for massive production of algae and weeds. As will be discussed in Chapter 5, however, removal of these structures is not consistent with the water quantity objectives.

CHAPTER 5

PLANNING ALTERNATIVES

5.1 SUMMARY OF PLANNING OBJECTIVES

The purpose of the Supplementary Qu'Appelle Agreement is to prepare a plan to provide for flood control and flood plain management, to maintain static water levels and to reduce water pollution in the Moose Jaw River. For this study a number of management alternatives were identified for three areas of study - adjustment to the flood hazard, water quantity and water quality - and considered in relation to the planning objectives established for the study.

The planning objectives for adjustment to the flood hazard are:

(1) Immediate Planning Objectives:
Reduce property damage, economic and social disruption and the threat of loss of life in developed areas on the flood plain.

(2) Long Range Planning Objectives:
Minimize the potential for property damage, economic and social disruption and the threat of loss of life on the flood plain.

The planning objectives for water quantity management are:

(1) To maintain the Kingsway, C.P.R., and Gulf Dams at full supply level.

(2) To provide a continuous flow of water in the Moose Jaw River through the city of Moose Jaw.

The planning objective for water quality management is:

(1) To achieve a level of water quality in the Moose Jaw River that meets the Specific Surface Water Quality Objectives recommended by the Qu'Appelle Basin Study Board for adoption in the Qu'Appelle River Basin.

These water quality objectives are outlined in Table 7.

There are both tangible and intangible benefits to be realized from the achievement of these objectives. In the case of adjustment to the flood hazard, the major benefits relating to the immediate planning objectives take the form of a reduction in property damages and social disruption for existing flood plain occupants. Property damage can be expressed in monetary terms and social disruption can be quantified in terms of the number of persons or residences occupying the flood plain. Disaster prevention as it relates to loss of life is an intangible benefit. In the case of both water quantity and water quality objectives the benefits to be obtained are related primarily to aesthetic and recreational values and, as such, are intangible benefits and cannot be quantified in any meaningful way.

The costs of most structural alternatives have been estimated, however, for some of the more broadly based management programs which were considered it has not been possible to estimate costs. Neither the time nor the resources were available in this study to define such programs in sufficient detail to allow cost estimates. In any event, the benefits that accrue from most such programs are largely intangible and do not lend themselves to economic evaluation.

5.2 DISCUSSION AND ASSESSMENT OF ALTERNATIVES

Some of the management alternatives considered in this study relate, either positively or negatively, to the planning objectives in two or more of the planning areas: flooding, water quantity,

and water quality. Other alternatives relate specifically to one particular planning area. The management alternatives considered are discussed and assessed in the following paragraphs, beginning with those which relate to more than one planning area.

5.2.1 Comprehensive Management Alternatives

5.2.1.1 Upstream Storage: Retaining a portion of the high spring flow in the river above Moose Jaw in storage reservoirs for gradual release throughout the remainder of the year would provide streamflow through the city. Depending upon reservoir capacity some flood control could also be realized from upstream storage.

The upstream storage alternatives considered are outlined in Chapter Two. They are: Lower Site, Upper Site, Site X, Modified Upper Site, Summer Water Supply Reservoir, and nine small reservoirs.

The Lower Site, with 64,000 acre-feet of storage capacity, has the greatest potential both for flood control and for augmentation of streamflow. If streamflow above the reservoir could be forecast perfectly, an ideal condition analogous to perfect weather forecasting, and if the control structure was regulated accordingly, water levels in the Churchill Park-Wellesley Park area could be reduced by approximately two feet for both the 2% (1:50) and 1% (1:100) flood and by about one-half foot for the Probable Maximum Flood. Without perfect forecasting, water levels could be reduced by a lesser amount. In addition, the Lower Site Reservoir could provide a guaranteed minimum monthly flow of 17 cubic feet per second through the city.

The 20,000 acre-foot capacity Upper Site Reservoir with perfect forecasting could be operated to reduce water levels in the Churchill Park-Wellesley Park area by one foot for the 2% (1:50) and 1% (1:100) floods and by one-half foot for the Probable Maximum Flood. Without perfect forecasting there would be no appreciable water level reduction. The Upper Site Reservoir could provide a guaranteed minimum monthly flow of nine cubic feet per second through the city.

Neither the Site X nor the Modified Upper Site reservoirs, each with a storage capacity of 10,000 acre-feet, would afford flood control benefits, but either could provide a guaranteed minimum monthly flow of five cubic feet per second through the city. The alternative involving nine smaller reservoirs, with a combined storage capacity of 2,200 acre-feet, would provide no flood control benefit and no measurable year round augmentation of flows through the city. The Summer Water Supply Reservoir was specifically designed to maintain a static water level and a flow of water through the impoundments within the city during the summer season. It would have little effect on flood flows.

In economic terms the flood control benefits that could be obtained from these upstream reservoirs are insignificant when compared to the costs. If all flood damage to existing development could be avoided, the present value of the benefit that would be realized is about $89,000. By comparison, the Lower Site Reservoir would cost $6.0 million and the Upper Site Reservoir $3.7 million. The most effective of these alternatives, the Lower Site Reservoir, would reduce the area flooded and the damages incurred by about one-half for most floods. The Upper Site Reservoir would provide even less protection, and the remaining alternatives have no measurable flood control benefits.

It is estimated that a flow of one cubic foot per second is required to maintain static water levels behind the impoundments in the city of Moose Jaw. The Lower Site at 17 cubic feet per second, the Upper Site at 9 cubic feet per second, and Site X and the Modified Upper Site, each at 5 cubic feet per second, could provide sufficient flow to maintain static levels and to provide streamflow through the city. These flows would meet the aesthetic requirements for water quantity. From the point of view of water quality, however, it has been estimated that even at flows of up to 100 cubic feet per second

from upstream storage, the nutrient load in the river would still be sufficient to support massive growths of algae and weeds.

The Summer Water Supply Reservoir could be operated within a range that could provide a continuous flow through the city of from 17 cfs for two months to 8 cfs for four months. Any operating level within this range would be adequate to maintain static water levels in the impoundments and to provide a visible flow through the city, thus meeting the aesthetic requirements for water quantity. Alternatively, it could be operated to provide slug flows of 250 cfs of two days duration twice each year if required to refill reservoirs within the city de-watered for weed control. This flow could also be used to flush out the system. With this alternative the impoundments would not be maintained at the full supply level at all times, and there would not be a continuous flow of water through the city. However, it would provide the opportunity to experiment with harvesting and flushing of algae and weeds to enhance the aesthetic value of the impoundments. To maintain a water supply of acceptable quality the Summer Water Supply Reservoir would probably have to be treated to control aquatic plant growth.

No environmental impact studies of the reservoirs themselves were carried out, however, it could be anticipated that they would provide conditions suitable for algal and weed growth. There would be some disruption of agricultural operations and traffic patterns in the areas developed for reservoirs; while these factors were recognized in estimating costs, they cannot be disregarded in considering the overall impact of the reservoirs. Recreation benefits at the reservoir sites were also considered, but with the competition from the Qu'Appelle Valley, the potential for algae, and the fluctuations in water level required to operate the reservoirs for flood control and to augment downstream flows, there would be little recreation benefit.

5.2.1.2 Dredging: The potential for dredging the river bottom within the city to improve water quality, to enhance the usable water surface area, and for flood control was examined. A number of areas where dredging would be beneficial were identified and outlined in previous chapters.

The benefits from dredging the C.P.R. Reservoir to enhance its aesthetic and recreational value are non-quantifiable. The dredging operation would remove all obstructions within five feet of the surface of the reservoir, would clear the shoreline of the existing weed growth, which is extensive in some areas, and would deepen the channel adjacent to the shoreline for boating and to control unsightly mudbars and weed growth. The sedimentation studies indicate that the Moose Jaw River appears to be in equilibrium, but since little is known about the sediment contribution of the tributary streams it was not possible within the budget for this study to estimate the rate of re-deposition of sediments, or to assess the long term effectiveness of dredging the reservoir. The cost of this dredging operation has been estimated at $23,000. No attempt was made to identify or evaluate the environmental impact of this operation, including the disposal of the dredged materials.

Four areas were identified where dredging would possibly modify the carrying capacity of the channel. These were in the area of the Spring Creek outfall, the channel immediately upstream from the C.P.R. Dam and adjacent to the residential areas of River Park, and Churchill Park. While these dredging operations would remove some obstructions in the channel, they would not result in any appreciable reduction of water levels under flood conditions. The effect would be more noticeable if combined with the removal of some of the structures that create impoundments in the river. As was the case for dredging of the C.P.R. Reservoir, the long term effectiveness could not be assessed, and the environmental impact, if any, is unknown.

The quantities of oil, minor elements, and nutrients in the sediments behind the High Pressure and C.P.R. Dams, and in Thunder Creek near the mouth, are sufficient to be harmful to some forms of aquatic life. Removal of these sediments would improve the aquatic habitat, and would be effective over the long term if point sources of pollution were controlled so that new impurities could not build up as sediment accumulates on the bottom. No cost estimates for these dredging operations are available, however, the cost of dredging the C.P.R. reservoir is likely comparable to the $23,000 estimated for dredging to enhance the aesthetic and recreational value.

5.2.1.3 Removal of Structures: The four dams in the Moose Jaw River within the city - Kingsway, C.P.R., High Pressure, and Gulf - create a backwater effect under flood conditions, and the impoundments created by these dams provide ideal conditions for the growth of algae and weeds.

Removal of the Gulf, High Pressure and C.P.R. Dams would provide a measurable reduction in water levels as far upstream as the Sioux Bridge. However, since the effect would be limited to the Industrial area, flood damages would be reduced by only a few thousand dollars. Removal of the C.P.R. and High Pressure Dams without removal of the Gulf Dam would not provide a similar benefit.

Unless nutrient concentrations in the Moose Jaw River can be reduced to a level where they will not support algal growth, or unless some other means can be found to control algal growth, the impoundments in the city will continue to be infested with algae. Removal of the impoundments within the city would limit the area where algal growth can take place. This alternative is, however, in direct conflict with the objectives for water quantity, which require maintenance of the existing impoundments at the full supply level since the city views the reservoirs as an aesthetic attribute. Unless another solution to the algal problem can be found, the citizens of

Moose Jaw are faced with a choice between alga-ridden reservoirs or no reservoirs at all.

5.2.1.4 Importation: During the course of the Saskatchewan-Nelson Basin Board Water Supply Study, a canal from the Qu'Appelle River to the Souris River to carry water imported from Lake Diefenbaker was investigated. A secondary canal to divert water from the main canal into the headwaters of the Moose Jaw River was also investigated. The estimated cost of the works required to divert 200 cubic feet per second to the Moose Jaw River was $2.7 million. This alternative was not examined any further in the present study. However, the costs compare favourably with the upstream storage alternatives considered in this study and should be considered as a possibility for the future. The effect of a 200 cubic foot per second diversion on water quality in the Moose Jaw River would depend in part upon the quality of the water diverted from the Qu'Appelle River.

5.2.2 Specific Management Alternatives

5.2.2.1 Adjustment to the Flood Hazard

Dykes: The dyking alternatives evaluated in this study were outlined in Chapter Two. Where dyking was considered feasible from an engineering point of view, cost estimates were prepared for dykes that would provide protection from floods up to and including the 1% (1:100) flood. An evaluation of the various dyking alternatives is presented in Table 9. For this table the present value of benefits and the operation and maintenance portion of the costs were calculated using a discount rate of 7% over a 50-year period. At the 7% rate, which is considered a reasonable expression of the current borrowing rates of the federal and provincial governments, about 97% of the maximum benefit would be realized in fifty years. The number of residences affected was converted to the average annual number of residences affected to be comparable with the economic evaluation.

TABLE 9 : EVALUATION OF DYKING ALTERNATIVES MOOSE JAW

DYKE	COST[1]	BENEFIT[2]	NET BENEFIT	B:C	TOTAL NUMBER OF HOMES AFFECTED	AVERAGE ANNUAL NO. OF HOMES AFFECTED
1% (1:100)						
Churchill Park						
Aesthetic	138,500	23,740	-114,760	0.17:1	68	1.68
Non-Aesthetic	69,700	23,740	-45,960	0.34:1		
Wellesley Park						
Aesthetic	25,350	3,850	-21,500	0.15:1	8	0.13
Non-Aesthetic	23,200	3,850	-19,350	0.16:1		
Industrial[3]						
A	18,900	6,320	-12,580	0.33:1	2	0.02
B	11,700	360	-10,340	0.03:1		
2% (1:50)						
Churchill Park						
Aesthetic	48,400	15,570	-35,430	0.32:1	41	1.13
Non-Aesthetic	31,800	15,570	-16,230	0.49:1		
Wellesley Park						
Aesthetic	7,400	2,460	-4,940	0.33:1	4	0.07
Non-Aesthetic	6,550	2,460	-4,090	0.38:1		
River Park	34,200	550	-33,650	0.016:1	7	0.07
Industrial[3]						
A	11,000	2,460	-8,540	0.22:1	0	0
B	1,700	250	-1,450	0.14:1		

[1]Cost = Capital cost plus operation and maintenance costs for 50 years discounted at 7%.

[2]Benefit = Present value of the average annual damages discounted at 7% for 50 years.

[3]For purposes of evaluating the dyking alternatives the Industrial area was considered in two parts: A is the area from the C.P.R. Dam to the High Pressure Dam.
B is the area from the High Pressure Dam to the sewage pumping station.

As is apparent from Table 9 none of the dyking alternatives are economically feasible. A significant number of houses in Churchill Park would be protected by dykes designed for the 1% (1:100) flood. It is doubtful if it would be acceptable to dyke Churchill Park without also dyking Wellesley Park, however, since dykes in Churchill Park would undoubtedly raise the water level in Wellesley Park to some extent. The non-aesthetic design dykes are significantly less expensive than the aesthetic design in Churchill Park, and somewhat less expensive in Wellesley Park. However, even dykes designed with aesthetic considerations in mind might not be acceptable to residents in Churchill Park, particularly those whose homes are adjacent to the river.

Economic considerations aside, dykes do not, by themselves, provide an acceptable degree of flood protection. Serious consideration should be given to dykes only if they are a component of a more comprehensive system of flood protection that incorporates other structural and non-structural measures.

Flood Plain Zoning: Flood plain zoning is directed at minimizing the potential for damage in the flood hazard area. One benefit to be realized from zoning is that flood damage could be limited to what it is at present. The extent of this saving is not quantifiable. A zoning plan could be developed that would not alter the existing land use pattern, but would provide the city with strong controls over future development on the flood plain. With the exception of the additional administrative costs required to implement a zoning plan this program would add nothing to the normal cost of administering the city's zoning by-laws. This management alternative is entirely consistent with the long range planning objective of minimizing the potential for flood damage.

Land Purchase: To convert the residential property on the flood plain to a use less susceptible to flood damage, such as

for recreation, would cost, at 1973 prices, an estimated $2.6 million for property purchase alone. For Churchill Park, which includes 70% of the residences on the flood plain, the cost would be $1.8 million. There would be additional costs involved in reclamation of these areas for another use. The cost element aside, any major program to relocate flood plain residents could prove to be more disruptive socially than a major flood.

The economic and social costs of a major program of land use change render this alternative unacceptable in the short term. There are, however, some specific areas where land use change through purchase could be effective over the long term.

The Kingsway Park area is at present zoned as a restricted development area. There is very little residential development in the area and the city is pursuing a policy of purchasing the remaining residential land, as it becomes available, for future conversion to park use. It would be consistent with the planning objectives for this study if the city were to continue to pursue this policy in the Kingsway Park area.

A long term program to purchase the residential property on the river side of Lansing St. would reduce the potential for flood damage in this area. This would also enhance the aesthetic value of the river in this area by affording improved access to the shoreline. Although there is a strip of Crown-Owned land adjacent to the river in this area, it has been infringed upon by the residents of Lansing St. to the extent that access to the river is severely limited.

There are only eleven residences in Wellesley Park, and a number of these are reaching the end of their useful lifetime. All of the non-residential land in this sub-division is owned by the city. Depending upon the city's priorities for recreation development, it would be consistent with good flood plain management to purchase residential property in Wellesley Park as it becomes available, and to convert this area entirely into park land.

As a long term flood plain management program and to enhance the aesthetic value of the river bank in the more immediate sense, a strip of the Saskatchewan Power Corporation's land adjacent to the river bank in the vicinity of the C.P.R. Dam, including the area occupied by the old power house, could be purchased and converted to open space. In addition to providing a protective buffer zone between the river and adjacent industrial land in the flood hazard area, an area of open space, if properly managed, would do much to enhance the aesthetic value of this potentially attractive area of the river.

Flood Proofing: Some suggested flood proofing measures are included in Appendix 4 of this report, but no attempt was made to estimate the costs or the potential benefits of implementing them. The success of any flood proofing measure depends to a very great extent on the diligence and energy of the individual property owner. Information from other flood areas, and the experience in Moose Jaw in 1969 as indicated in the response to the Residential Data Survey, suggest that the benefits from flood proofing exceed the quantifiable costs.

Flood Forecasting, Warning and Emergency Action: To be most effective, flood forecasting, warning, and emergency action must be considered as individual components of a single program. To ensure that the maximum amount of time is available between the flood forecast and the occurrence of the flood event, and that all reasonable emergency procedures are executed during this time, there must be an overall program design that will facilitate the necessary coordination, information flow, and action procedures.

No attempt was made to detail the type of program required for Moose Jaw, however, the Saskatchewan Department of the Environment has developed an improved flood forecasting program for the Moose Jaw River which will be operative by the spring of 1974. Effective warning and emergency action programs must also be developed and

procedures established to coordinate all the components into a single overall program. Some authority must undertake to plan and organize such a program.

Responses to the Residential Data Survey conducted for this study indicate that while there was not a highly sophisticated flood warning system in operation and emergency action was not fully organized, the precautions that were taken by residents during the 1969 flood were effective in reducing damage. The total damage to homes and contents reported by all respondents to the survey, 70% of whom were resident in the flood plain in 1969, was $16,000. The estimated potential damage to homes and contents from a 2% (1:50) flood is $27,000. These totals are not exactly comparable since responses were not received from all persons resident in the flood plain in 1969 and since the 1969 flood was closer to a 1:60 than a 1:50 flood. However, they suggest that the benefits from emergency measures are significantly greater than the costs.

5.2.2.2 Water Quantity

Control Structures: To meet the water quantity objective of maintaining the impoundments within the city at full supply level the control structures must be in good repair. It was determined that the Gulf and C.P.R. Dams are in generally good condition. However, to bring them up to standard and to minimize leakage from these structures, will require repairs estimated at $2,000 for the C.P.R. Dam and $1,000 for the Gulf Dam.

The full supply level of the Gulf Dam controls water levels upstream to the C.P.R. Dam. Thus, the High Pressure Dam, which is in poor condition, serves no useful function as a water control structure and there is no need to repair it for this purpose. However, it serves as a river crossing structure for two trunk sewer lines and carries an important traffic bridge. The repairs required to restore this structure to a condition adequate to carry the sewer

lines and the bridge are estimated to total $47,000. Alternatively, replacement of this structure with a bridge and a sewage lift station should be considered.

5.2.2.3 Water Quality

Sewage Treatment and Disposal: The Qu'Appelle Basin Study Board in its report of January 1973 recommended measures for treatment and disposal of sewage from the Canadian Forces Base and the city of Moose Jaw. These recommendations are consistent with the conclusions reached in this study. Since a detailed study of these measures will be required prior to their implementation, no attempt was made to estimate their costs in this study. Terminating the disposal of Canadian Forces Base effluent upstream from the impoundments in the city would eliminate a major source of the nutrients that support algal and weed growth.

Control of Upstream Sources of Nutrients: The land in the upper reaches of the Moose Jaw River Basin is used almost exclusively for agricultural purposes. The run-off waters from this land contain nutrients in sufficient quantities to support algal and weed growth throughout the length of the Moose Jaw River. Nutrients are contributed to water courses from a variety of land use practices, including cropping and livestock production.

To eliminate algae and weeds in the Moose Jaw River within the city of Moose Jaw nutrient concentrations in the river water must be reduced to a level that will not support their growth. Because the nutrient concentrations in streamflow reaching the city from the upper reaches of the Basin contain enough nutrients to support algal and weed growth, control of nutrients within the city will have only a minor effect.

Control of Algal and Weed Growth: There are several chemicals that could be used to control algal and weed growth, however, it was not possible to estimate the cost or the effectiveness of chemical control with any certainty. The species of weeds in the impound-

ments would have to be identified before a herbicide could be selected, and the number of chemical applications required each year would have to be determined from experience. A disadvantage of chemical control is that the dead weeds remain in the system and create a significant oxygen demand as they decay.

Mechanical weed harvesters are available that could remove aquatic weeds from the system without de-watering the impoundments. This would avoid the problem of excessive oxygen demand associated with chemical treatment. A weed harvesting unit costs approximately $35,000, however, and the cost of purchasing a unit for use in Moose Jaw alone may not be justified.

One method of operating the Summer Water Supply Reservoir would provide an opportunity to experiment with the control of algal and weed growth in the impoundments within the city. The C.P.R. and Gulf Reservoirs could be de-watered on two occasions during the summer season and the weed growth in the reservoirs killed by several days of exposure to the sun. The reservoirs could then be re-filled by releasing a flow of 250 cubic feet per second from the Summer Supply Reservoir for a period of two days. In the process the Kingsway and High Pressure Reservoirs would be flushed out and the dead weeds from the C.P.R. and Gulf Reservoirs would be carried downstream. This method of controlling weed growth has been used successfully in the canals in the Western Irrigation District in Alberta. As an alternative to flushing the dead weeds downstream it might prove feasible to harvest them prior to re-filling the impoundments. This method of reservoir operation could also be used in combination with chemical control of algal and weed growth in the impoundments. Some method of algal and weed control may also have to be applied in the Summer Water Supply Reservoir for this method to be effective.

The Qu'Appelle Basin Study Board in their January 1973 report recommended that the most appropriate methods for controlling algal

and weed growth in surface waters should be determined and applied. The implementation of the recommendations of the Qu'Appelle Basin Study Board is being negotiated by the federal and provincial governments. This program could come up with methods which would be effective in Moose Jaw.

CHAPTER 6
CONCLUSIONS

6.1 FLOOD HAZARD

For the purposes of this study, the flood plain, or the flood hazard area, of the Moose Jaw River within the city of Moose Jaw was defined as the area that would be inundated by the Probable Maximum Flood. Within this area there are 745 acres of land: 47 acres in residential use, 117 acres in industrial or commercial use, 5 acres in institutional use, 236 acres in agricultural use, and 340 acres of recreational land and urban open space. There are 140 residences and 10 commercial or industrial establishments in the flood hazard area. The residential population was estimated at 475 persons. The largest and most intensively occupied residential area is the Churchill Park sub-division, which includes 70% of the acreage in residential use and 70% of the residential population of the flood plain. The average annual damage from floods of all frequencies of occurrence has been estimated at $6,425. The present value of this damage is $88,670.

The range of alternative adjustments to the flood hazard considered included upstream storage, dykes, channel modification, removal of control structures, land purchase, flood plain zoning, flood proofing, and a flood forecasting, warning and emergency action program.

The only upstream storage alternative that would provide any effective flood control is the Lower Site Reservoir. The cost of this reservoir has been estimated at $6.0 million. Under the most perfect operating conditions this alternative would reduce flood water levels by about two feet for floods with a probability of

occurrence of 1% or less, which would reduce damage by about one-half from $90,000 to $45,000. With the low level of damage and the high cost of upstream storage this alternative is not economically feasible for flood control.

None of the dyking alternatives evaluated are economically feasible. In all cases the benefit to cost ratio for dykes was less than 0.5:1. For Churchill Park the dyking alternative with the highest ratio of benefits to costs, 0.49:1, is a dyke, designed with no aesthetic constraints, to protect against the 1% (1:100) flood.

Neither channel modification by dredging, nor removal of the control structures on the river within the city would result in any significant reduction in flood damage. Removal of the control structures would eliminate the impoundments within the city, contrary to the city's wishes to retain these for their aesthetic value.

Any large scale program to change the existing land use in the flood hazard area would not be economically feasible, and could be more disruptive socially than a flood. There are small areas, however, where changes in land use effected over the long term would reduce the potential for flood damage.

Amendments to the existing zoning by-laws and zoning plan for the flood hazard area that would restrict development in certain areas and require flood proofing measures to be taken in areas where development is allowed would limit the potential for flood damage in future years.

Both flood proofing measures implemented by individual flood plain occupants and a coordinated program of flood forecasting, warning and emergency action would appear to have potential for reducing flood damages in Moose Jaw. An educational program based on the above measures, and dissemination of maps defining the flood hazard area, which could be made available as a result of this study, would assist flood plain occupants in adjusting to the flood hazard.

6.2 WATER QUANTITY

There are three effective impoundments on the Moose Jaw River within the city: Kingsway Dam, C.P.R. Dam, and Gulf Dam. The C.P.R. Reservoir in particular has some potential for recreational use, and all are considered to have aesthetic value by city officials.

There is a fourth dam in the river, the High Pressure Dam, which is inoperative as a water control structure, but serves to carry two sewer lines and a bridge across the river. The full supply level of the Gulf Dam, immediately downstream, exceeds the sill elevation of the High Pressure Dam by some three feet. Thus, if the Gulf reservoir is maintained at the full supply level, consistent with the planning objectives for this study, it effectively controls the water level upstream to the C.P.R. Dam.

Since there is virtually no flow in the Moose Jaw River between the month of June and the spring break-up, a number of upstream storage sites were examined as a means to augment stream flow. The Lower Site Reservoir, which would cost $6.0 million, could supply a guaranteed minimum monthly flow of 17 cubic feet per second. The Upper Site Reservoir, which would cost $3.7 million, could supply a guaranteed minimum monthly flow of nine cubic feet per second. As has been pointed out, neither of these alternatives are economically feasible for flood control. Either the Site X Reservoir, which would cost $2.6 million, or the Modified Upper Site Reservoir, which would cost $3.0 million, could supply a guaranteed minimum monthly flow of five cubic feet per second. Neither of these alternatives would provide any flood control benefit. The alternative which involves nine small reservoirs, at a cost of $660,000, would provide no measurable year round flow and no flood control benefit. If flows were to be augmented only during the summer months, benefits could be realized from a reservoir with as little as 200 acre-feet capacity if it were located close to the city. The 2,000 acre-foot

reservoir assessed in this study could supply either a reasonably dependable flow of 17 cubic feet per second for the months of July and August, or two complete refills of the impoundments in the city. The cost of this reservoir is estimated at $886,000.

Minor repairs to the C.P.R. Dam costing $2,000, and to the Gulf Dam costing $1,000, would be necessary in order to minimize leakage from these structures at the full supply level.

Although this alternative was not considered in any detail, it was noted that if a canal to divert water from Lake Diefenbaker to the Souris River was ever developed, a secondary canal could be built to carry water to the upper reaches of the Moose Jaw River. The Saskatchewan-Nelson Basin Board has estimated that a secondary canal to convey 200 cubic feet per second would cost $2.7 million.

6.3 WATER QUALITY

The water quality studies indicated that for a number of parameters the water quality in the Moose Jaw River does not meet the objectives established by the Province of Saskatchewan. The nutrient concentrations in the headwaters of the river system are sufficient to cause massive algal and weed growths in impoundments, in backwaters, and along shorelines throughout its entire length. The nutrient concentrations are increased after receiving the effluent from the Canadian Forces Base at Moose Jaw and from the city of Moose Jaw sewage treatment facilities.

Significant amounts of total dissolved solids are added to the river from the Canadian Forces Base, the city of Moose Jaw and the C.P.R. car cleaning operation. Significant quantities of oils and minor elements: copper, lead, zinc, and mercury were found in the river system. The quantities of oil, minor elements, and insecticides in the sediments behind the C.P.R. and High Pressure Dams are sufficient to be harmful to aquatic life.

The results of analyses for coliform and fecal coliform bacteria were too erratic to allow meaningful conclusions to be drawn and therefore require further investigation.

Augmentation of flow in the river through Moose Jaw to dilute nutrient concentrations was considered. It was determined that flows as great as 100 cubic feet per second would not reduce the nutrient concentrations in the water of the Moose Jaw River to levels that would not sustain massive algal and weed growth, unless relatively nutrient-free water was used to augment flows. The upstream waters of the river are rich in nutrients, and the greatest guaranteed flow that could be provided from the upstream storage alternatives considered was 17 cubic feet per second.

The possibility of augmenting flows in the Moose Jaw River with water diverted from Lake Diefenbaker via the Qu'Appelle River and a canal to the Souris Basin has been mentioned. Any improvement in water quality in the Moose Jaw River that might result from this diversion would depend, in part, upon the quality of the imported water.

The removal of nutrients from the effluent of the Canadian Forces Base and the city of Moose Jaw is mandatory for an improvement in water quality in the downstream reaches of this river. Even if the effluent from the Canadian Forces Base were subjected to tertiary treatment, it could still contain sufficient nutrients to support algal growth in the impoundments on the river within the city. To completely eliminate the problem created by the effluent from the Base, disposal into the river must be terminated. The average flow of effluent from the Canadian Forces Base into the Moose Jaw River is 0.3 cubic feet per second; this is the only source of water supply to the river during the summer months. If this supply were no longer available, evaporation would lower water levels in the impoundments in the city by two feet rather than by one foot as at present.

The impoundments created by the dams in the river within the city provide ideal conditions for algal growth. Removal of these impoundments would greatly improve the quality of water through the city, but this would not be consistent with the water quantity objectives of maintaining these impoundments at the full supply level. Unless other means are effective in reducing the nutrient concentrations or in controlling algal growth, the city appears to be faced with a choice between alga-ridden reservoirs or no reservoirs at all.

A program for controlling weeds and algal growth with chemicals could be conducted on an experimental basis for a few years to determine the effectiveness and the costs of chemical control.

The surveillance of waste handling facilities on the Moose Jaw River must be continued, and a continuing program will be required to effectively monitor water quality in the Moose Jaw River.